GEOMETRY OF THE NORTHERN CARTER-KNOX STRUCTURE, ANADARKO BASIN, GRADY COUNTY, OKLAHOMA

By

BRIAN P. HOFFMAN

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Oklahoma State University

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Thesis Approved:

Ibrahim Cemen

Thesis Adviser

Darwin Boardman

Gary F. Stewart

Alfred Carlozzi

Dean of the Graduate College

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CHAPTER 1

INTRODUCTION

The Anadarko Basin trends northwestward and covers much of the central west half of Oklahoma and the east half of the Texas Panhandle. Bounding the basin to the north is the Northern Oklahoma Platform. Confining the basin to the east are the Central Oklahoma Platform, Hunton-Pauls Valley Uplift, and the Arbuckle Uplift. The southern portion is bounded by the Wichita-Criner Uplift (Figure 1). In addition to the high-relief bounding features, a long and complex growth history has produced a sedimentary basin in which accumulated sedimentary rocks have attained great thickness. In some wells drilled to 25,000 feet (7.6 km), basement rock has not been reached.

In Late Proterozoic, rifting of the area formed extensional lows on which the basin formed. A long period of subsidence, from Late Cambrian to Mississippian, allowed accommodation space needed to accumulate thousands of feet of sedimentary rocks.

In the Pennsylvanian, the collision of North and South America produced severe east-west compressional stresses that formed large shear or wrench-fault systems throughout southern Oklahoma. From this, many strike-slip faults and en-echelon folds were formed by reactivation of formed normal faults that controlled sedimentation in the Southern Oklahoma Aulacogen from Pennsylvanian to Permian. Faults and folds, combined with thick sections of sedimentary rocks, make the Anadarko Basin one of the most prolific oil and gas producers in the United States. Exploration for hydrocarbons in the basin began in the early 1900's. It has continued to increase since that time with the introduction of new technologies such as seismic, gravity, and magnetic data. Even with the maturity of the Anadarko, new discoveries are being made every day.

The Carter-Knox structure formed during the Pennsylvanian. It is eleven miles long and two miles wide. It is partially a subsurface feature of the Anadarko Basin. It trends northwestward. To date, the Carter-Knox oil and gas field has produced 404 trillion cubic feet of gas and 86 million barrels of oil. The producing formations are Pennsylvanian sandstones, Mississippian limestones, Devonian limestones and dolostones, and Ordovician limestones, dolostones, and sandstones.

STATEMENT OF PURPOSE

The study area lies within Grady County, Oklahoma. This includes the following townships: T3N, R5W; T3N, R6W; T4N, R5W; and T4N, R6W. The main purpose of this study was to determine the structural geometry and evolution of the northern half of the Carter-Knox structure. It focuses on timing and type of deformation. Specific objectives were to determine:

1. locations and types of major faults that are in the subsurface within the study area.
2. the dip separation on each of the faults.
3. the subsurface structural geometry of the northern Carter-Knox structure.

LOCATION OF THE STUDY AREA

The study area is the northern half of the Carter-Knox structure. In its entirety, the structure is an eleven-mile long and two-mile wide oil field in the southeastern part of the Anadarko Basin (Figure 1). The area is within Grady County, Oklahoma and includes all of T.4N., R.6W., the northeastern portion of T.3N., R.6W., the northwestern portion of T.3N., R.5W., and the southwestern portion of T.4N., R.5W. (Figures 2 and 3).

METHODS OF INVESTIGATION

The objectives of this investigation were met by examining available data about subsurface geology of the study area. The data examined were:

1. 181 electric logs obtained from the Oklahoma City Geological Society Well Log Library and Marathon Oil Company were used to locate the tops of specific marker beds, in order to prepare structural geologic cross-sections. These marker beds, from youngest to oldest, are the Springer Shale, Hutson sandstone, a marker bed known as the "boat marker", Caney Shale, Sycamore Limestone, Woodford Shale, Hunton Group, Sylvan Shale, and Viola Limestone; (Figure 8)
2. four 2-D seismic profiles provided by Marathon Oil Company, as well as a supervised examination of a 3-D profile, conducted in the Oklahoma City office of Marathon Oil Company.

These data were used to construct six structural cross-sections and two structural contour maps. The structural cross-sections were constructed by mapping the tops of the Hutson sandstone, "boat marker", Caney Shale, Woodford Shale, Hunton Group, Sylvan Shale, and Viola Limestone. Marker bed tops were correlated across the study area. Repetition of marker beds on well logs indicates reverse separation. These repetitions are common in wells penetrating the southwest flank of the structure. Two structural contour maps were constructed, of the tops of the Hutson sandstone and the Hunton Group.

PREVIOUS INVESTIGATIONS

Anadarko Basin

The Anadarko Basin formed as a portion of the Southern Oklahoma Aulacogen, in three recognized stages (Figure 4). These stages began with an initial rifting phase of a triple junction in Middle Cambrian, followed by a period of subsidence from Late Cambrian to Mississippian, and concluded by the deformation of strata in the Pennsylvanian to Permian.

The first stage to occur in formation of the Anadarko Basin was related to rifting of the Southern Oklahoma Aulacogen (Hoffman, Dewey, and Burke, 1974) (Figure 5). Formation of a hot spot caused the crust to bulge and crack. Three rifts formed as a result of the expanding lithosphere. These rifts radiated from a common center point. Igneous activity exhibited as extrusive and shallow intrusive rocks continued to force apart two of the rifts while the third eventually failed to open. The Carlton Rhyolite is evidence of extension because it is 500-550 million years old (Brown and others, 1985). A narrow deep basin formed in this abandoned rift and was filled by thick accumulations of sediments. Based on the age of the Carlton Rhyolite and the overlying Cambrian Reagan

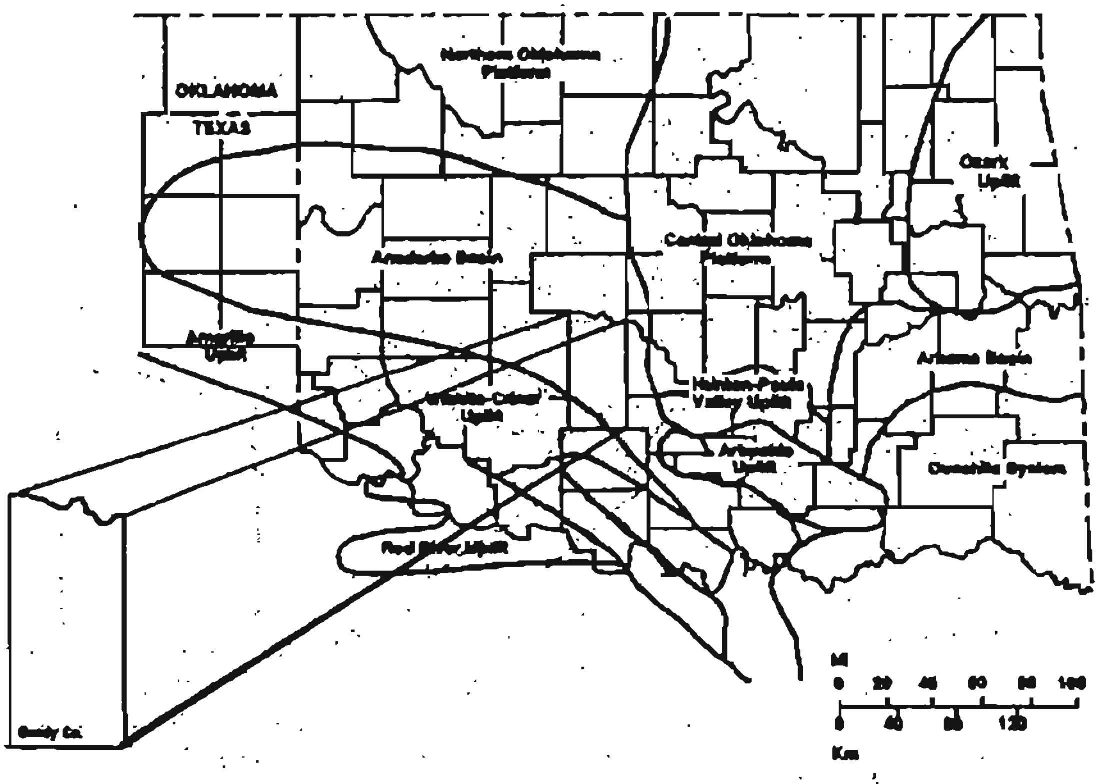

Figure 1. Tectonic provinces of Oklahoma.

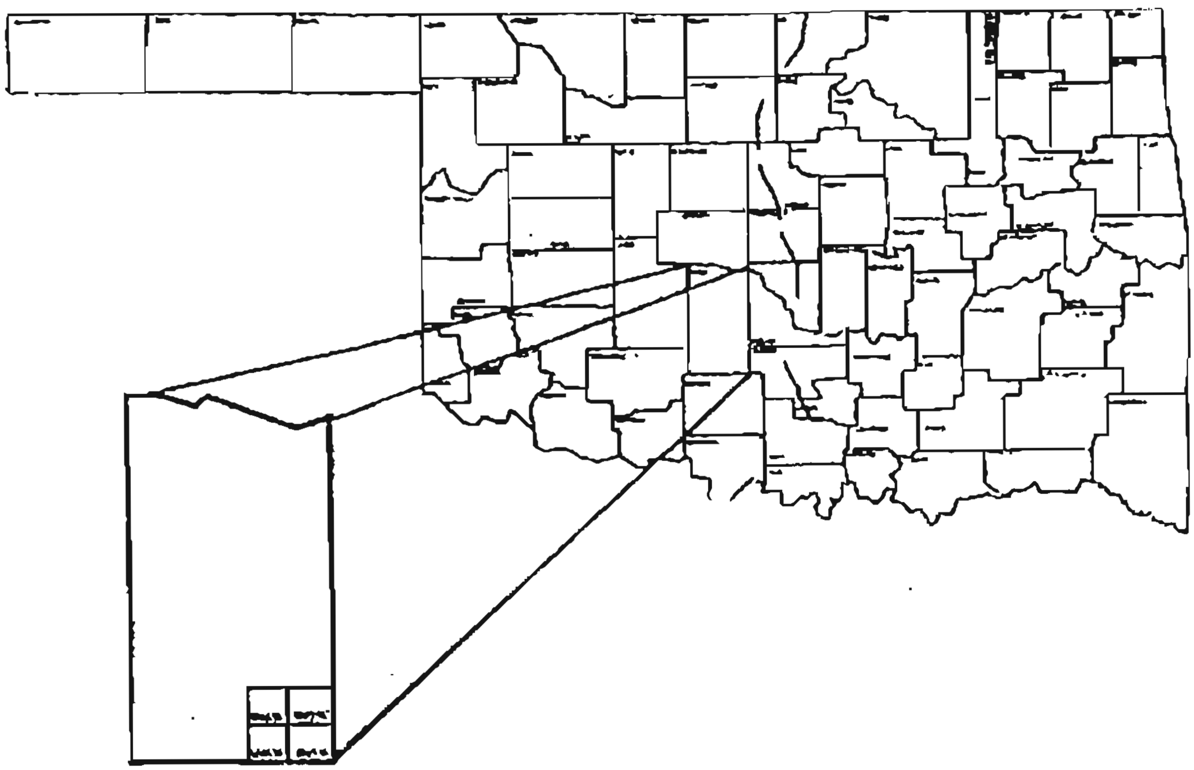

Figure 2. Location of study area.

Sandstone of the Timbered Hills Group of the Arbuckle Mountains to the east, the rifting stage of the Southern Oklahoma Aulacogen occurred in the Late Proterozoic to Late Cambrian.

The next phase to affect the basin was the subsidence of the Southern Oklahoma Aulacogen. During this episode the basin subsided rapidly and was infilled by thick layers of sediment from a marine transgression, which further added to the subsidence. Wickham (1978) indicated that the clastics of the Upper Cambrian Reagan Formation were evidence for the onset of subsidence. This subsidence was followed by the accumulation of thick carbonates formed on a passive shelf (Brown and others, 1985). This started in the Late Cambrian and lasted until Mississippian.

The Southern Oklahoma Aulacogen was subjected to orogenic forces during its deformation stage. The deformation stage was a result of a collision between North America and South America, or some other microplate (Perry, 1989) which produced the Ouachita fold-thrust belt of southern Oklahoma and western Arkansas. During this stage, many structures formed during the Cambrian rifting were reactivated as strike-slip faults (structural inversion). The Collings Ranch conglomerate was deposited in a pull-apart basin suggesting the presence of strike-slip faulting in the Pennsylvanian (Pybas, Cemen, and Al-Shieb, 1995). This deformation occurred from Pennsylvanian to Permian.

McBee (1995) suggested that the formation of the Anadarko Basin resulted from the formation of a megashear in the Southern Oklahoma Aulacogen. He stated that the Oklahoma Megashear formed as a result of east-west compressional shear stresses brought about by several orogenic events that lasted throughout the formation of the aulacogen. The main orogenic event to influence the Southern Oklahoma Aulacogen was called "Alleghenian" occurred in Early Pennsylvanian and refers to east-west stresses brought about by the collision of the North American (Laurentia) and South American plates.

Carter-Knox Structure

Although there are many technical reports provided by the oil company geologists working in the area, the only published material on the Carter-Knox structure is by Reedy and Sykes (1958). They interpreted the Carter-Knox as "three different traps formed at three different periods." (Figure 7). The first structure occurred in the Permian. It consists of two normal faults dying out at depth and paralleling the thrust faults. The second structure occurred in Pennsylvanian and consists of a northwestward trending fold that is faulted by several thrust faults. The final structure occurred in pre-Pennsylvanian. It also is an anticlinal fold but 1 mile west of the Pennsylvanian structure. No faults affect this structure.

Perkins (1997), studied the structural evolution of the southern half of the Carter-Knox structure. He concluded that the southern half of the Carter-Knox oil and gas field consisted of a wrench fault related structure. Perkins called it a "squeeze up" structure. It formed in the Pennsylvanian along a restraining bend of a strike-slip fault zone. Perkins' (1997) terminology was kept in this investigation to maintain continuity of names for the structures in both areas. The "squeeze up" structure included the Knox and Brickle faults and the Goddard Detachment (Figure 6). The Knox fault was interpreted to be a master fault extending the length of the structure. The Brickle is interpreted as being a splay of the Knox fault.

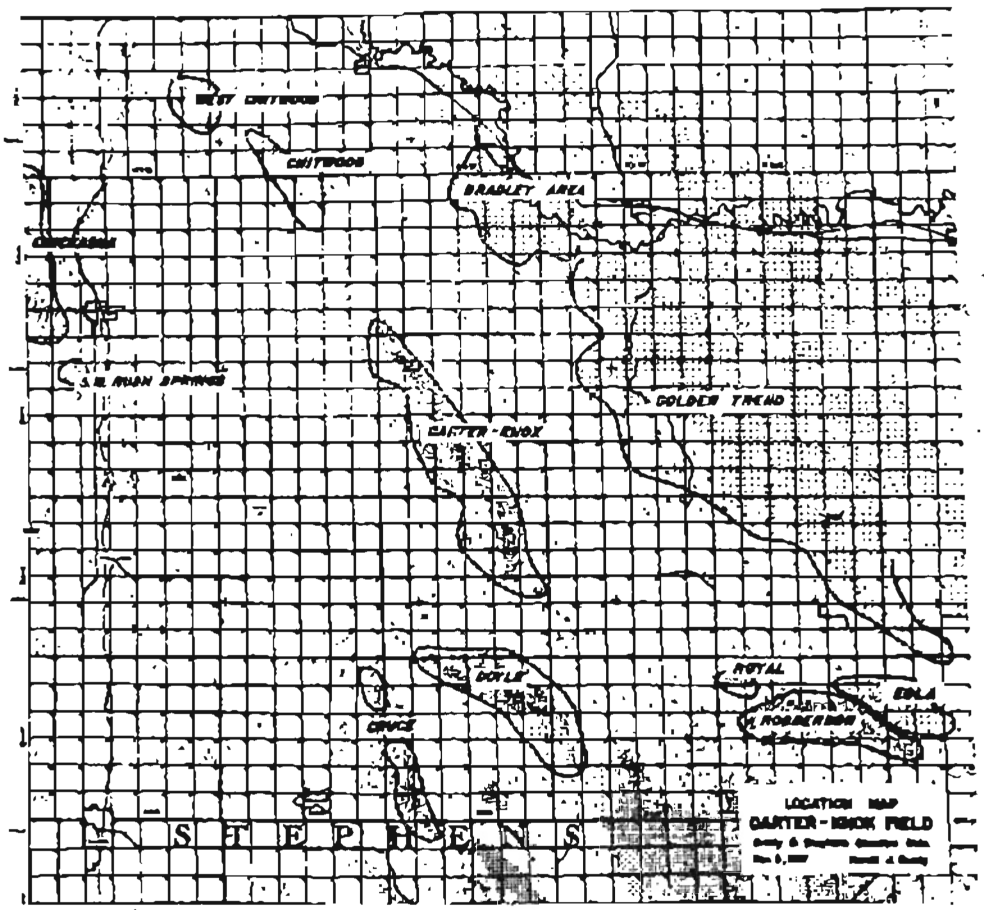

Figure 3. Location of Carter-Knox oil field (from Reedy and Sykes, 1958).

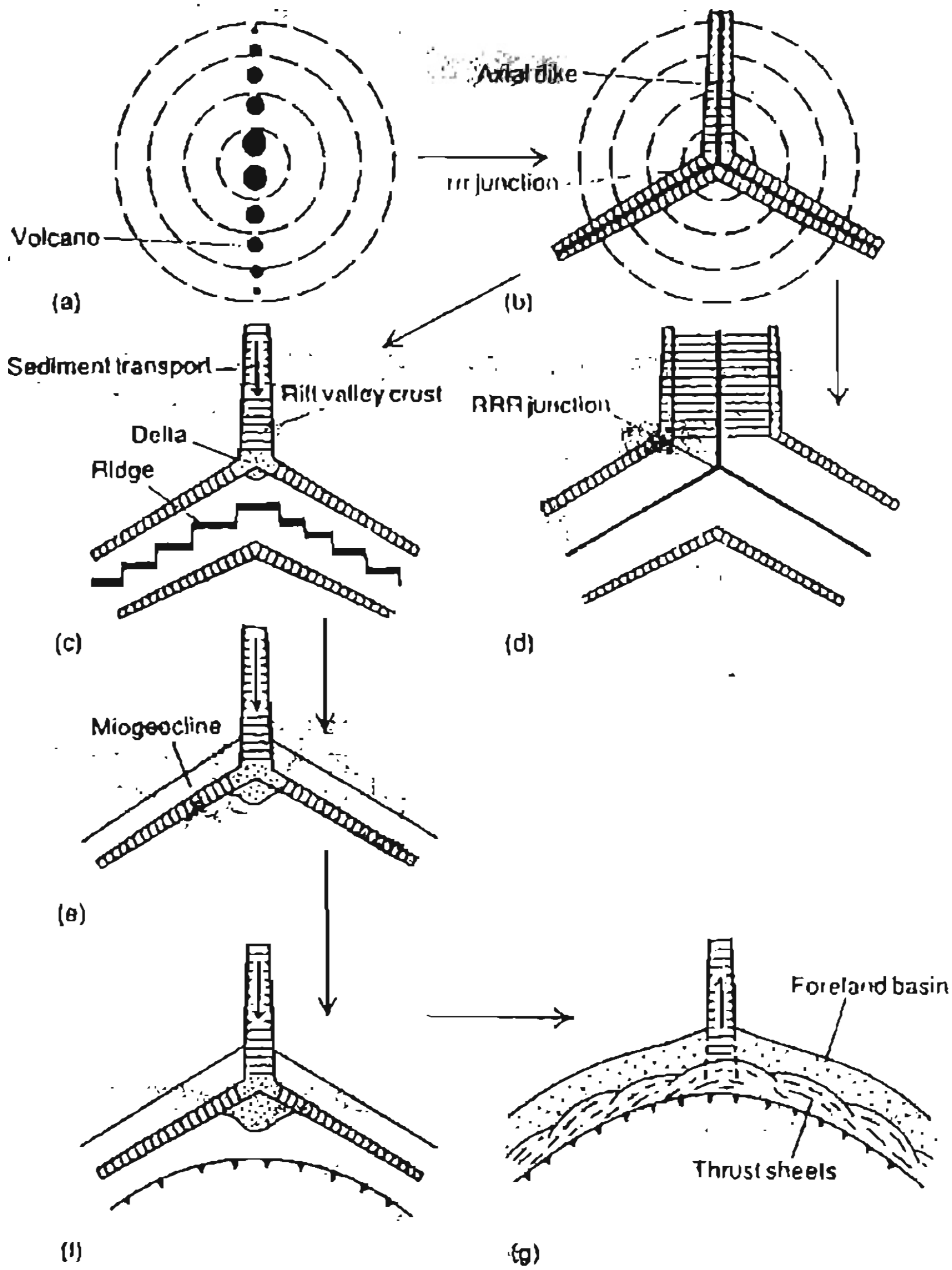

Figure 4. Diagrams showing the evolution of an aulacogen (from Burke and Dewey, 1973).

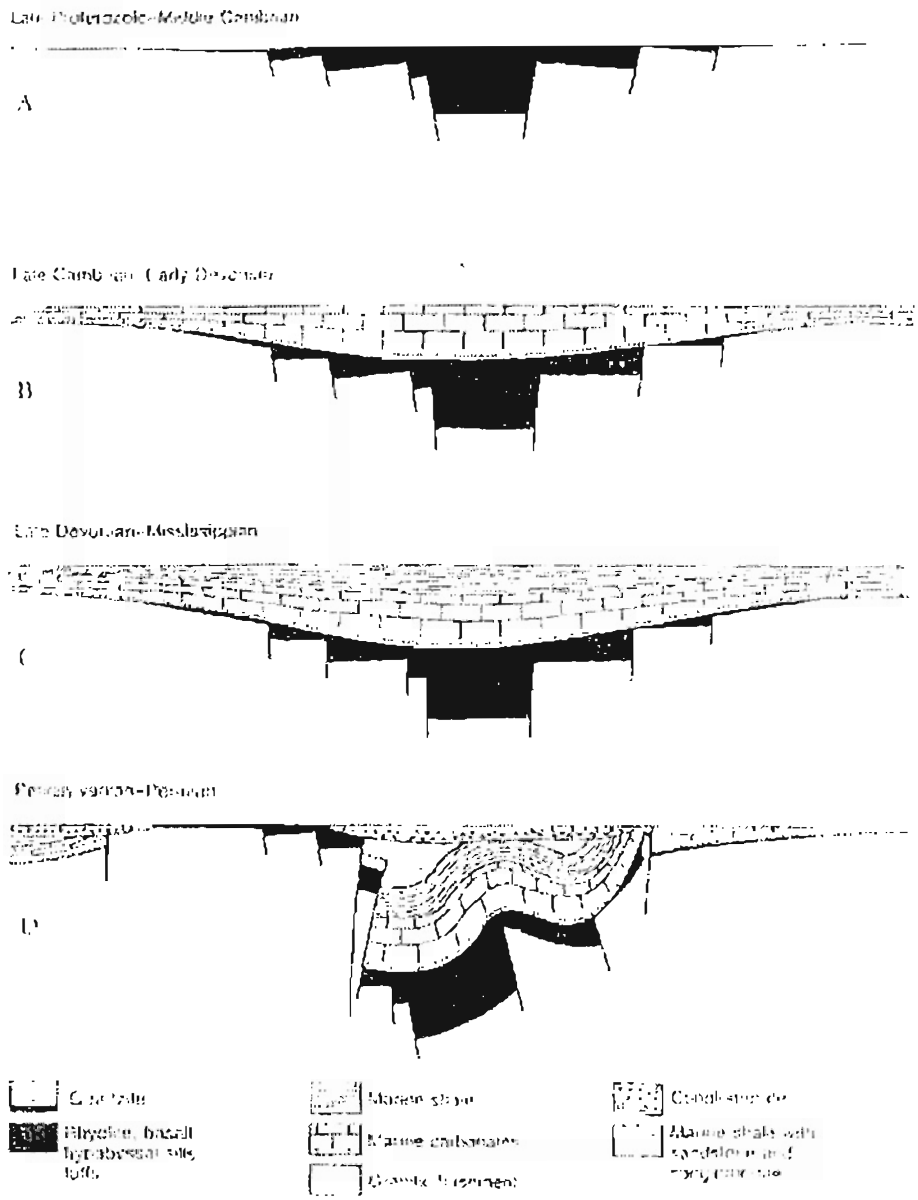

Figure 5. Stages of the formation of the Southern Oklahoma Aulacogen (from Hoffman, Dewey, and Burke, 1974).

The increased thickness of shale in the core of the "squeeze up" structure is attributed to the Goddard Detachment. Another structure that may be associated with the Carter-Knox is the Baker Anticline. Thinning of the Hunton on top of the anticline suggests a post Hunton unconformity. This may be an older anticlinal feature formed during the Silurian or pre-Woodford deposition. It was little affected by "squeeze up". This contradicts Reedy and Sykes (1958) hypothesis of 3 different structures that were formed at 3 different periods.

McCaskill (1998) conducted a facies and stratigraphic analysis on the strata surrounding the Eola fault at the southern end of the Carter-Knox field. From the data, he concluded that there were dramatic changes in the facies and stratigraphic thickness across the Eola fault in Devonian and older rocks. These changes occurred within a relatively short distance of .25 mile. Similar thickness of strata could be correlated to each other across the fault. However, there is approximately 16 miles of displacement between the areas of similar deposition and thickness. This large amount of separation and narrow band of deformation eliminated normal faults as being the cause of the separation. The only reasonable interpretation according to McCaskill could, therefore, be a left-lateral strike-slip fault. Perkins' (1997) interpretation of the strike-slip origin of the compressional structures along the southern part of the Carter-Knox structure is in full agreement with the interpretation of McCaskill (1998).

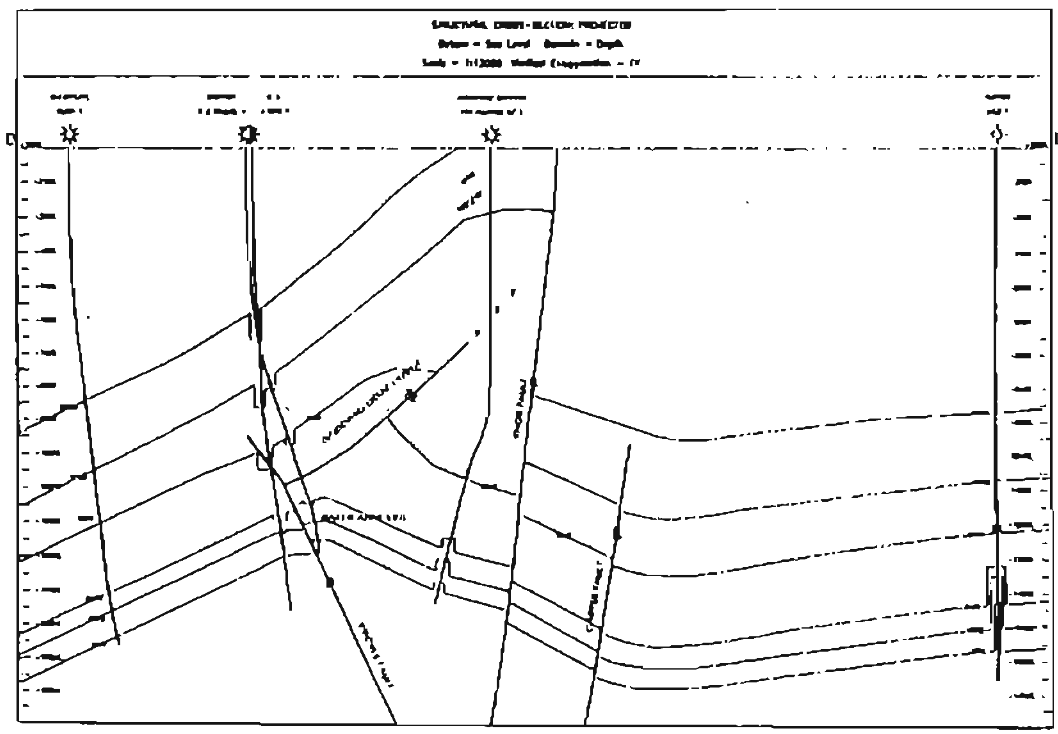

Figure 6. Northern cross-section from Perkins (1997).

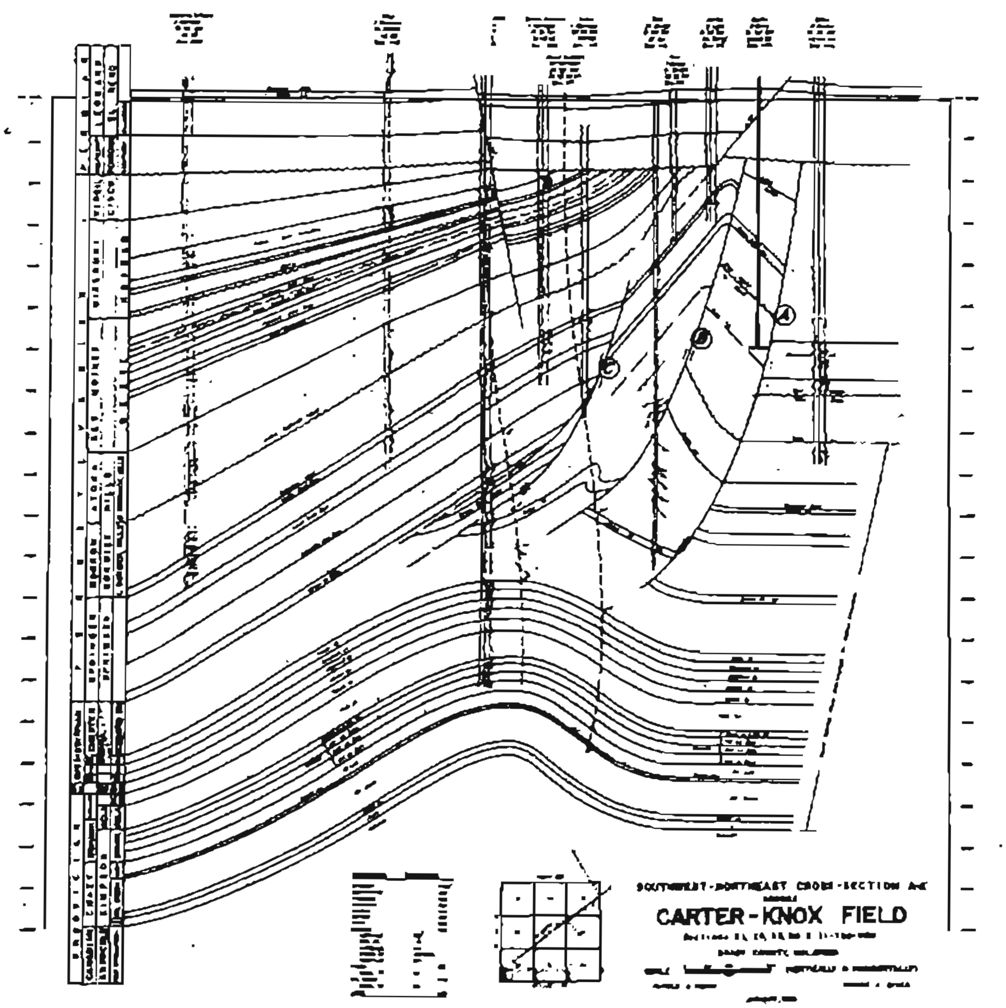

Figure 7. Reedy and Sykes, 1958, interpretation of the Carter-Knox structure.

CHAPTER II

STRATIGRAPHY OF THE ANADARKO BASIN

This paper deals only with rocks of Ordovician to Pennsylvanian age. Therefore pre-Ordovician rock units will be discussed very briefly. The Ordovician to Pennsylvanian rock units will be discussed in more detail, although not in depth since stratigraphy is not the main focus of this study. A list of references written on the stratigraphy of Paleozoic rock units of the Anadarko Basin is immense. For a more detailed description of Paleozoic rock units of the Anadarko Basin dealt with in this paper, the reader is referred, but not limited to Tomlinson (1959), Branson (1962), Kopaska-Merkel (1989), Lambert (1993), Harlton (1960), Maxwell (1959), and Shannon (1962).

PRE-ORDOVICIAN ROCK UNITS

The pre-Ordovician rock units refer to the Carlton Rhyolite and the Reagan sandstone of the Timbered Hills Group. No wells penetrate these strata in the study area and so will only be mentioned briefly. The Carlton Rhyolite is believed to be a remnant of igneous intrusives during the rifting stage of the Southern Oklahoma Aulacogen. It is dated 500-550 million years old (Brown and others, 1985). Immediately overlying the Carlton Rhyolite is the Reagan sandstone dated to the late-Cambrian.

MIDDLE ORDOVICIAN-PENNSYLVANIAN ROCK UNITS

There are no outcrops of formations used in the study in the immediate area. Therefore, lithologic descriptions of the rock units were compiled from other resources, especially Reedy and Sykes (1958) (Figure 8). The type log chosen for subsurface identification of various Ordovician to Pennsylvanian units is of the American Natural Gas Producing Company well Brown "A" No. 1. The well is in the center of the NW/4 of Sec. 12, T.4N., R.6W. It is used because of its location away from the structure, where the formations have not been deformed. Accurate thickness' and stratigraphic sequence orders were determined from this well (Figure 8).

The oldest formation that is concerned in this study is the Viola Limestone. It is Middle Ordovician and consists of 650 feet (198 meters) of gray crystalline limestone in the type log. Type log characteristics used to identify the Viola are: (1) low gamma ray, (2) high deep induction resistance, and (3) low conductivity (Figure 8).

Conformably overlying the Viola Limestone is the Upper Ordovician Sylvan Shale. The lower portion is a 60-80 feet (18-24 meters) brown, finely crystalline argillaceous dolomite. The upper portion is 290 feet (88 meters) of greenish gray, pyritic shale. Type log characteristics for the Sylvan Shale are: (1) high gamma ray, (2) low deep induction resistance, and (3) low conductivity (Figure 9).

The Hunton Group represents the Devonian and Silurian. It lies conformably over the Sylvan Shale. From the data, variations in stratigraphic thickness are interpreted across the study area due to the unconformity between the Hunton Group and the overlying Woodford Shale, but in most places in the study area it is about 280 feet (85 meters) thick. It is gray limestone that contains chert.

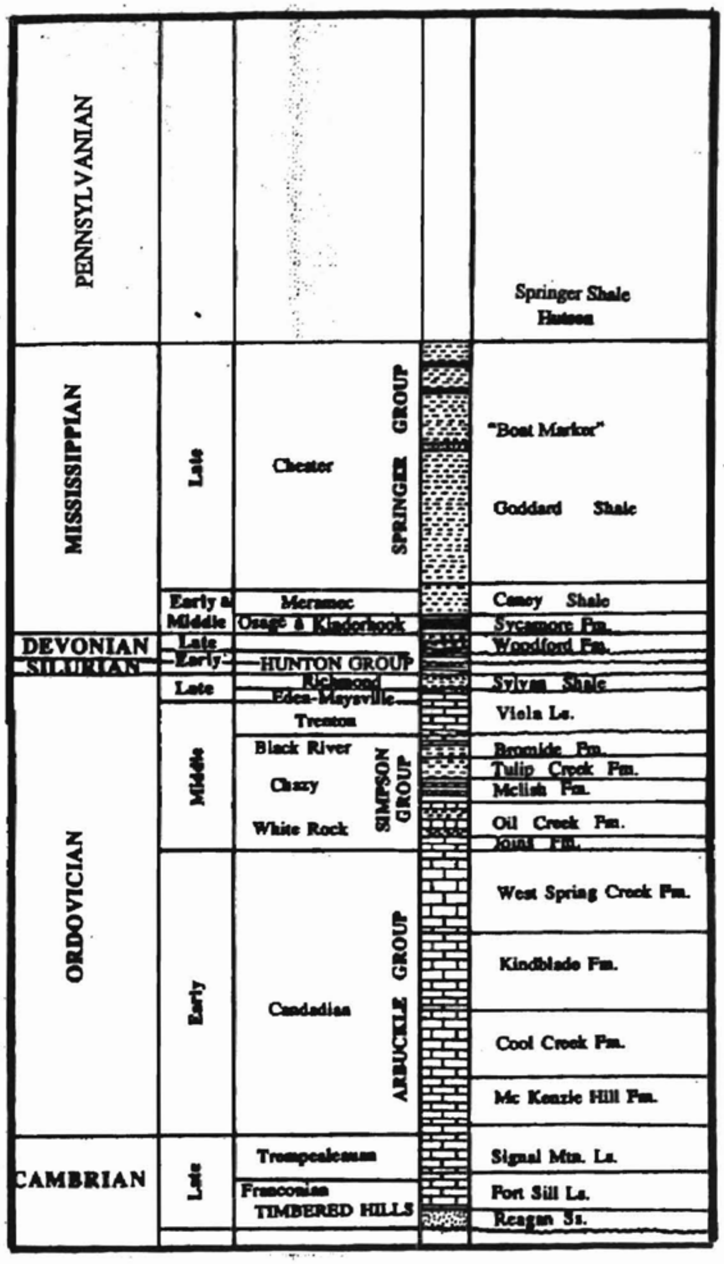

Figure 8. Generalized stratigraphic chart for Arbuckle Mountains, Oklahoma (modified from Pybas, Cemen, and Al-Shaib, 1995).

The lower 40-50 feet (12-15 meters) is pink crystalline limestone with some glauconite. Type log characteristics for the Hunton Group are: (1) low gamma ray, (2) high deep induction resistance, and (3) low conductivity (Figure 10).

The Woodford Shale unconformably overlies the Hunton Group. It is Late Devonian to Early Mississippian in age. It consists of 230 feet (70 meters) of black pyritic shale in the type log. Type log characteristics for the Woodford Shale are: (1) off scale gamma ray, (2) high deep induction resistance, and (3) low conductivity (Figure 10).

The Mississippian Sycamore Limestone conformably overlies the Woodford Shale and is about 230 feet (70 meters) thick in the type log. It consists of gray limestone in the upper part and cherty dolomite in the lower part. Type log characteristics of the Sycamore Limestone are: (1) moderately low gamma ray, (2) high deep induction resistance and, (3) low conductivity (Figure 10).

Conformably overlying the Sycamore Limestone is the Caney Shale. In the type log, it is 200 feet (61 meters) of gray to brown shale that is Mississippian. Type log characteristics of the Caney Shale are: (1) moderately high gamma ray, (2) low deep induction resistance, and (3) low conductivity (Figure 10).

The Goddard Shale represents the Late Mississippian. In the type log, it is 1400 feet (427 meters) thick and is composed of gray to dark gray fissile shales with some siderite. Type log characteristics of the Goddard Shale are: (1) moderately high gamma ray, (2) low deep induction resistance and, (3) high conductivity (Figure 11).

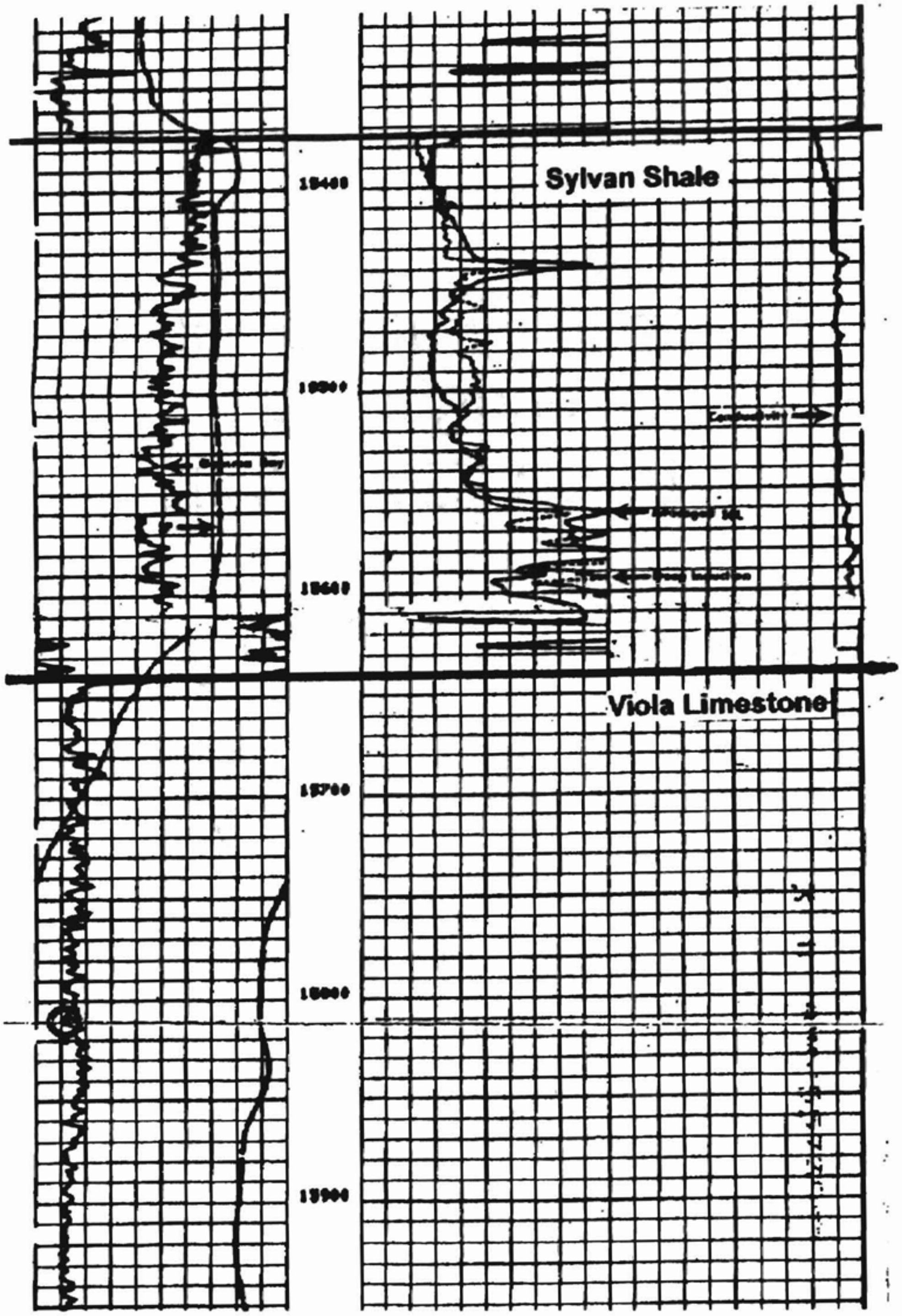

Figure 9. Log signatures of the Viola and Sylvan (from American Gas Brown "A" No. 1)

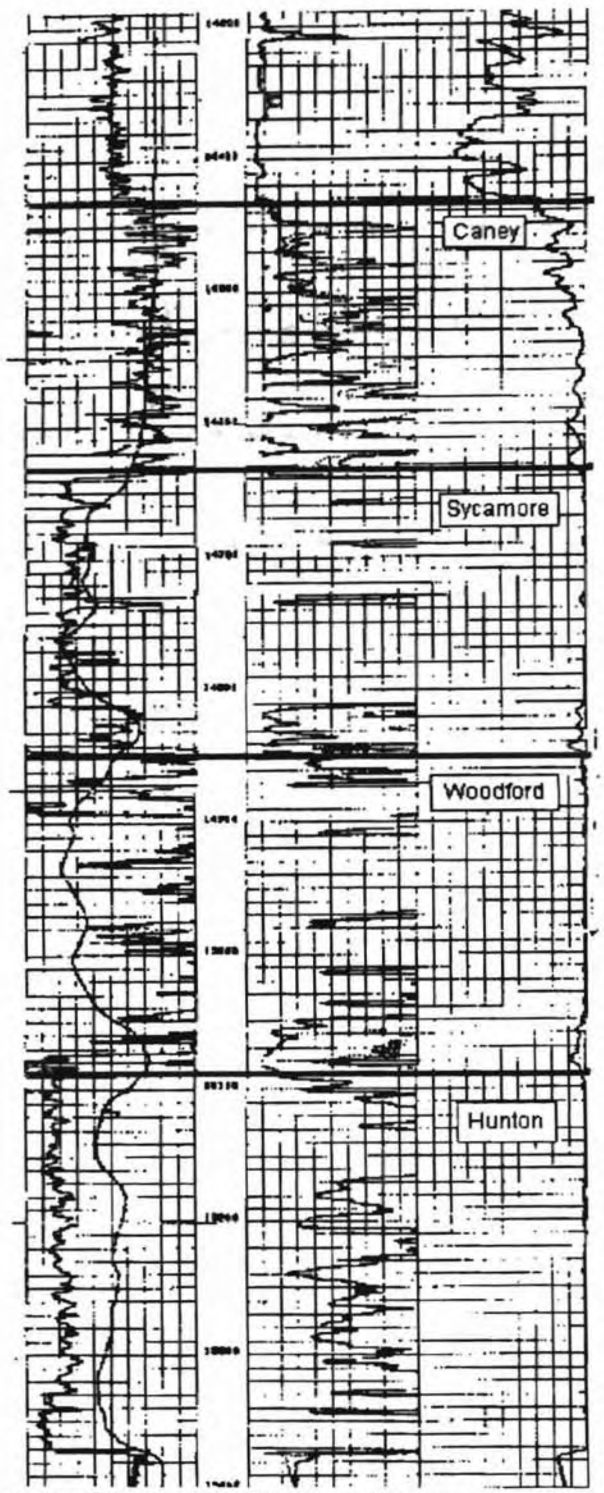

Figure 10. Log signatures of the Hunton, Woodford, Sycamore, and Caney (from American Gas Brown "A" No. 1)

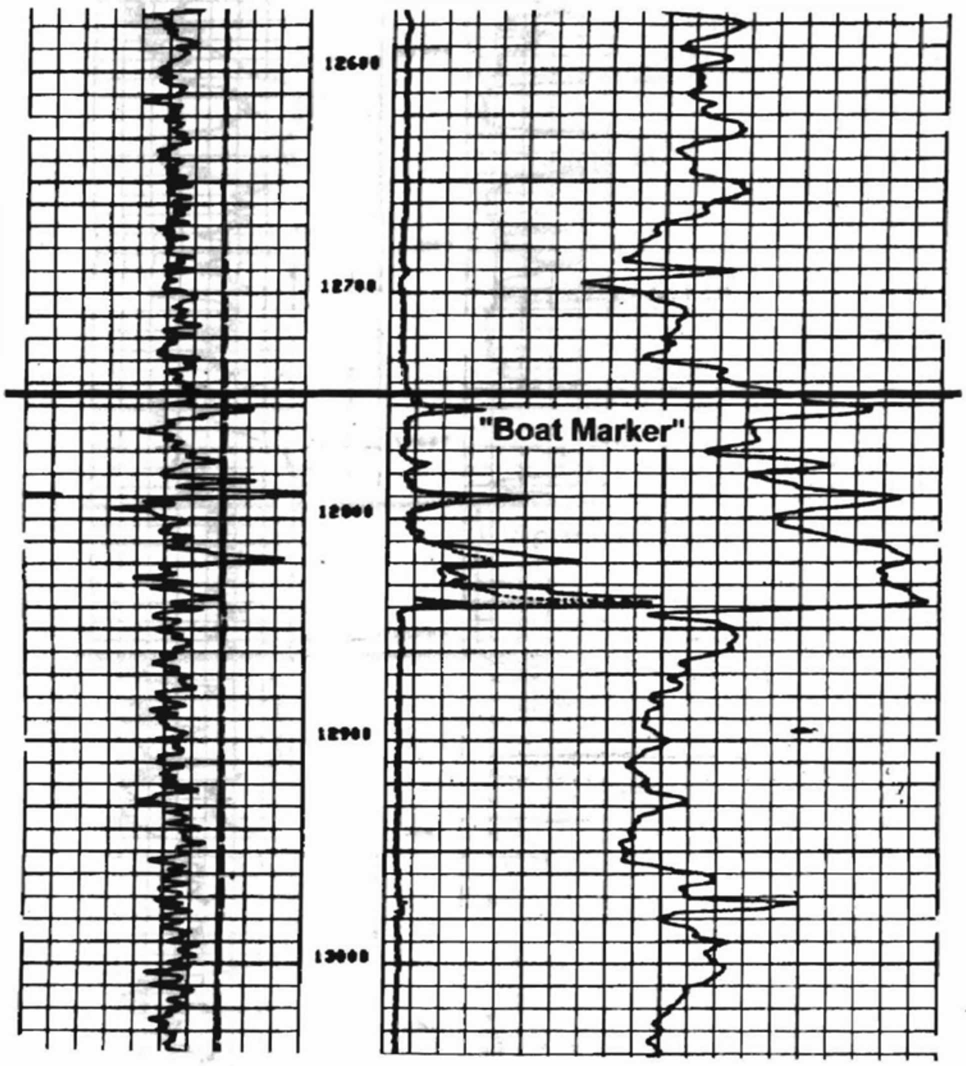

Figure 11. Log signature of the "boat marker" (from the American Gas Brown "A" No. 1).

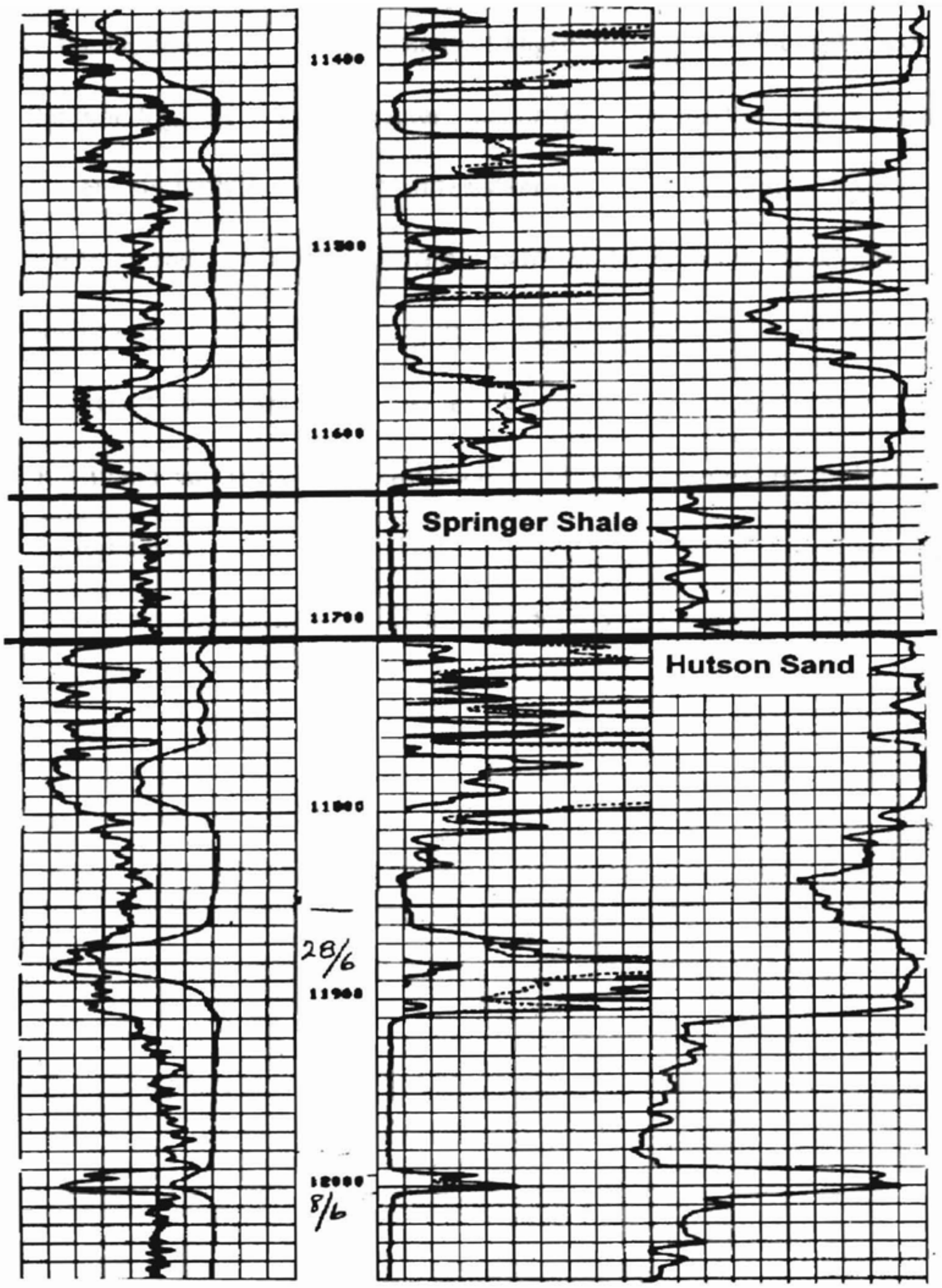

Figure 12. Log signatures of the Springer Shale and Hutson sandstone (from American Gas Brown "A" No. 1).

The "boat marker" is an informal name used by the oil industry for a key marker bed above the Goddard Shale and consists of approximately 100 feet (30 meters) of black shale in the type log. Type log characteristics of the "boat marker" are: (1) high gamma ray, (2) moderately high deep induction resistance and, (3) moderately high (Figure 11).

Overlying the Goddard Shale conformably is the Springer. It is Early Pennsylvanian in age and is the upper portion for this study. In the type log, it is 3,400 feet (1037 meters) of sandstones and shales. Within the Springeran in the study area, there is the Hutson sandstone. The Hutson is 150 feet (46 meters) of slightly glauconitic sand. Type log characteristics of the Hutson are: (1) moderately low gamma ray, (2) high deep induction resistivity and, (3) low conductivity (Figure 12).

CHAPTER III

STRIKE-SLIP FAULTS

The Carter-Knox structure is interpreted in this study area as a part of the Pennsylvanian strike-slip fault system of southern Oklahoma. Therefore, a brief description of strike-slip faults and associated structures will be given below.

Strike-slip faults are faults on which most of the movement is parallel to the fault's strike. Lengths of these faults range from 10's to 1000's of kilometers (Sylvester, 1988). Displacements vary from a few 10's of meters to a few 100's of kilometers on average. Belts of these faults form along zones of weakness in the crust. These belts form as a result of "horizontal" shear forces. Another term used to describe strike-slip faults is wrench faults. There is no difference between faults known as strike-slip faults and wrench faults. They both describe high angle strike-slip faults that involve the basement rock. (Figure 15).

Wilcox, Harding, and Seely (1973) devised a simple experimental model to explain the mechanics in a simple shear setting. This experiment provided a 3-D model for the structural features along wrench zones. They assumed the crust of the earth was made up of homogeneous sediments. A sheet of clay was used to represent the sedimentary cover (Figure 13a). First to form along the zone of movement was a series of folds. These folds were en-echelon or parallel and of similar shape and extent. As deformation continued, fractures formed within the folds. The smaller conjugate strike-slip faults that branched out 10°-30° from the strike of the main fracture zone are called synthetic strike-slip faults or R-shears. The conjugate fractures that form at high angles to the main fracture zone are called antithetic strike-slip faults or R'-shears. The linking of all the smaller strike-slip faults within the shearing zone came together in the final stages of the deformation process. As deformation continued, displacement along the fractured zone increased but in a narrow band. Finally, all the displacement occurred on a few faults or one main fault in a very narrow band of deformation. From experiments done with clay cakes by Wilcox, Harding, and Seely (1973), a predictable geometry of associated structures can be observed (Figure13a-b). Harding (1974) demonstrated the pattern using the strain ellipse (Figure 14).

If a bend occurs along a strike-slip fault, an area of compression or extension can be formed. The resulting structures are called flower structures. Where there is a local compression formed by the movement of two sides moving in opposite directions, a convergent zone is created (Figure 16). Structures formed in a convergent zone are called positive flower structures. Antiforms that are cored by thrust faults dominate positive flower structures. Where two sides move away from each other they form a gap. Here, divergent zones are created (Figure 16). Negative flower structures are formed containing synforms and normal faults. Pull-apart basins can be formed as a part of this extension, also.

Pitfalls

Flower structures are difficult to interpret using geophysical data (Harding, 1990). Seismic lines across strike-slip fault zones are often "noisy," with no prominent traceable events in the crucial area of interpretation. "Many structures imaged with reflection seismic can resemble a wrench fault system because of the great diversity of strike-slip faults and the wide range of contractional and extensional features associated with these faults" (Harding, 1990). Credible identification requires these criteria: "(1) narrow, long, straight, throughgoing master fault or zone of deformation, (2) steep to moderate dip of the master fault at depth, (3) offset of the top of basement, (4) changes in relative upthrown side, separation sense, and/or fault dip direction at depth or along strike of the master fault, (5) narrow fault slices within the master fault zone that steepen and join at depth (negative and positive flower structures), (6) different separation sense and orientation of relative upthrown side at these fault slices, and (7) coeval, en echelon flanking structures" (Harding,1990). In the subsurface, positive flower structures exhibit a geometric relationship similar to thrust faulted terrains and the negative flower structures show a geometry similar to normal faulted terrains. The steep angles of the faults disperse the sound waves penetrating the ground not allowing the energy to be focused and thus providing poor data quality. Along a strike-slip fault zone, not only are the faults difficult to see, but the strata underlying them prove to be elusive as well. Often positive flower structures may be interpreted, while in reality a negative flower structure is present. Salt and shale intrusions may also mimic the flower structure seismic pattern. Steep normal faults may appear as a negative flower structure. The key to an ideal interpretation is well control. Wherever possible, more than one seismic line along the length of the structure is needed.

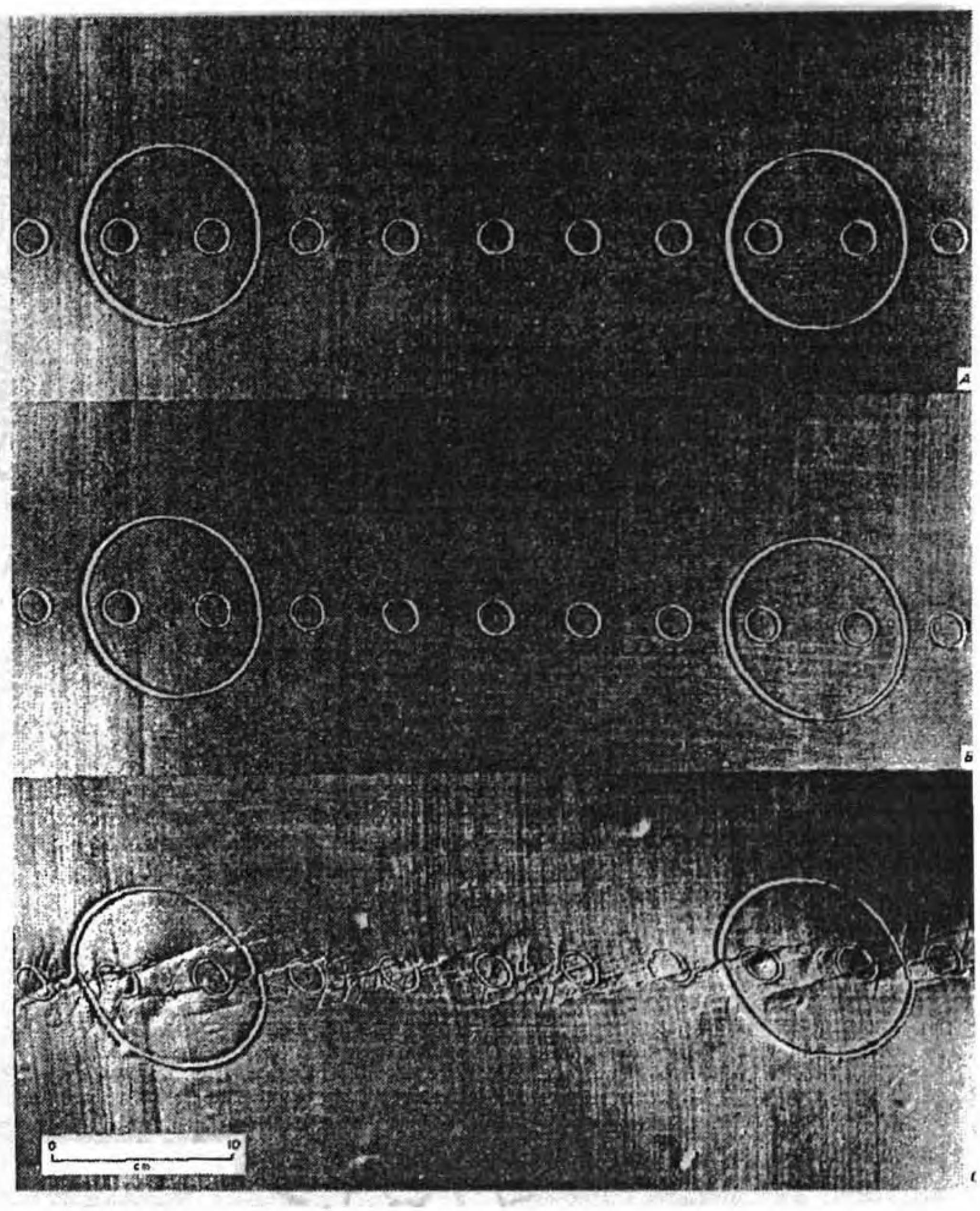

Figure 13a. Illustrations of clay cake experiments done by Wilcox, Harding, and Seely, 1973 showing the initial deformation along a strike-slip fault zone.

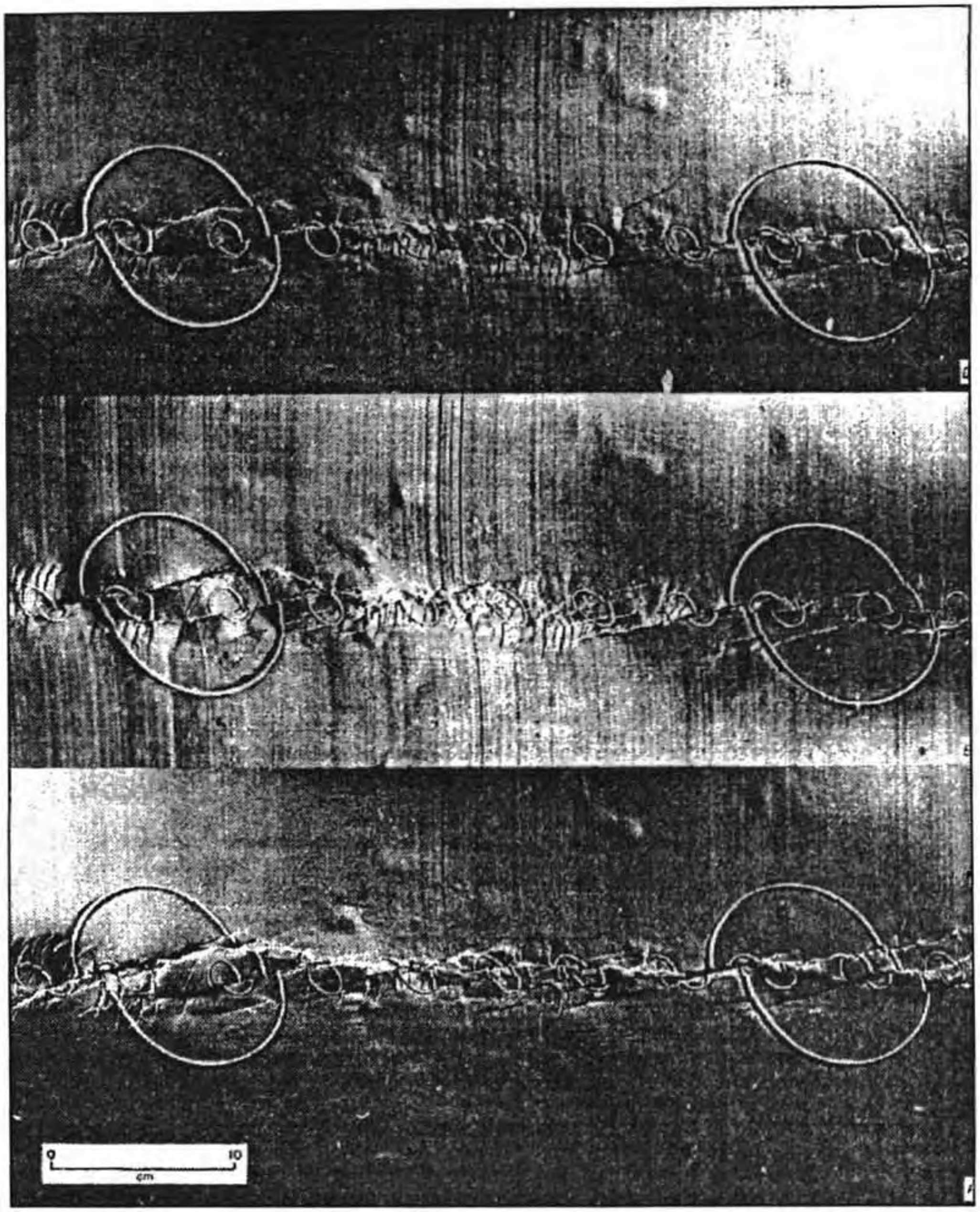

Figure 13b. Illustrations of clay cake modeling of wrench faulting (from Wilcox, Harding, and Seeley, 1973) showing the final stages of deformation along a strike-slip fault zone.

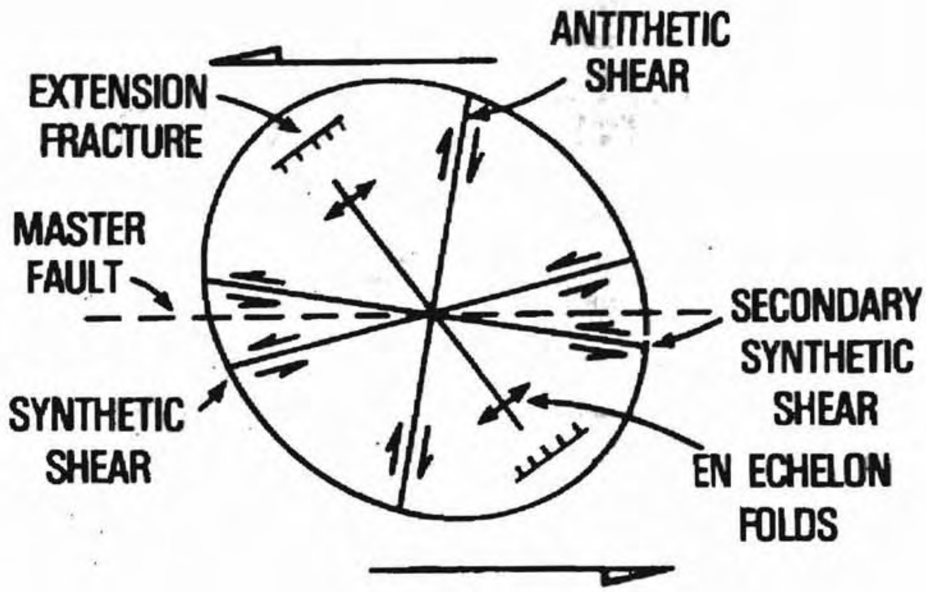

Figure 14. Strain ellipse of left-lateral wrench fault showing predictable geometries of deformation (from Biddle, 1985).

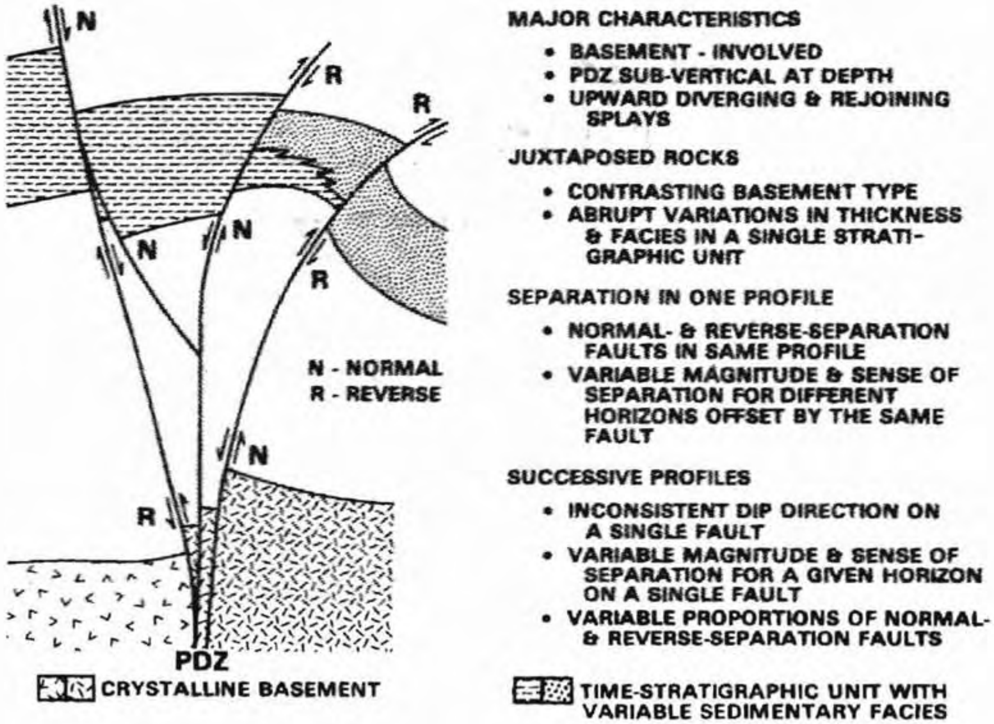

Figure 15. Typical cross-section of a wrench fault (from Biddle, 1985).

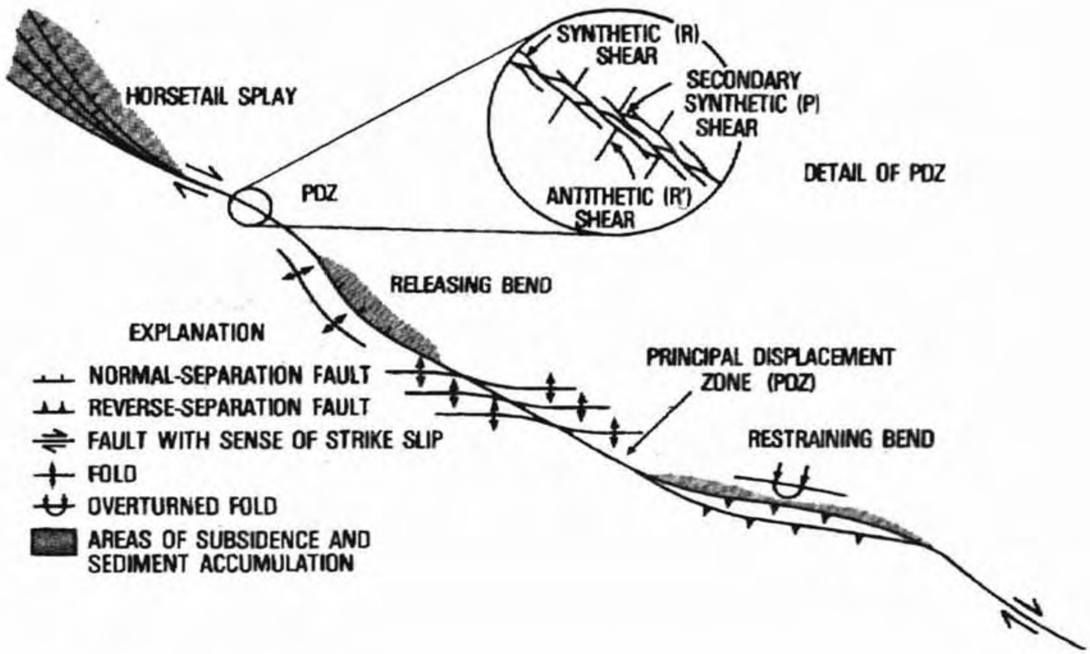

Figure 16. Map view of convergent and divergent zones along a right-lateral wrench fault (from Biddle, 1985).

CHAPTER IV

STRUCTURAL GEOLOGY

In this chapter, major faults and folds recognized in the area based on the subsurface interpretation of the available data will be discussed.

To interpret the structural geometry of the Carter-Knox structure, six cross-sections (Figures 17-22) and two structural contour maps (Figures 23-24) were constructed using well logs and seismic lines donated by Marathon Oil Company. Several marker beds were used in the correlation of well logs. They are the Hutson sand, "boat marker", Caney, Woodford, Hunton, Sylvan, and Viola. The electric log of the American Natural Gas Company Brown "A" No. 1 located in NW/4 of Sec. 12, T.4N., R.6W. was used as a type log. Faults in the study area were interpreted from well log and seismic data.

Plate I is a base map showing locations of the wells used in this study. Plate II shows the locations of the structural cross-sections. The cross-sections are Plates III - VIII. Structural contour maps were constructed using the top of the Hutson (Plate IX and Figure 23) and Hunton (Plate X and Figure 24). Appendix I contains information gathered from well logs in the study area for use in construction of cross-sections and structural contour maps.

The cross-sections and seismic data in Figures 17-33, top of Hunton structural contour map Figure 24, and seismic lines in Figures 26-32, indicate that an anticlinal feature stands out in the Carter-Knox structure. Perkins (1997) named it the Baker Anticline. It trends northwestward and extends the length of the study area. Deformed strata in the Baker Anticline include the Caney, Sycamore, Woodford, Hunton, Sylvan, and Viola formations.

Seismic data also suggest the presence of a well-developed high angle through-going fault on the northeast side of the Baker Anticline, trending northwestward (Figures 26-33). Perkins (1997) named this fault the Knox fault and it is interpreted as the master fault of the wrench system that dips to the southwest.

A second fault seen on seismograms parallels the Knox fault to the southwest but dips to the northeast (Figures 26-33). Perkins (1997) named this fault the Brickle fault. If the dip remains constant to the northeast it may join the Knox fault at depth. From Perkins (1997), the Brickle fault is interpreted as a splay of the Knox fault. It trends northwestward but does not extend north of cross-section A (Figure 17).

A third fault, named the Carter fault by Perkins (1997), is also seen on seismogram (Figures 26-33). The Carter fault lies to the northeast and parallels the Knox fault and dips to the northeast. It is interpreted as having reverse separation and trends northwestward.

Four 2-D seismic lines donated by Marathon Oil Company were used in conjunction with the well data to construct accurate cross-sections.

The first line is in the southern part of the study area, and parallels cross-section line A-A' (Plate III) and is perpendicular to the Carter-Knox structure. Figure 26 (Plate XI) shows the uninterpreted version of the most southerly seismic line. Figure 27 (Plate XII) shows the interpreted version of the same seismic profile. The eastern half of the seismic line exhibits little to no structural relief in the Hutson and Hunton.

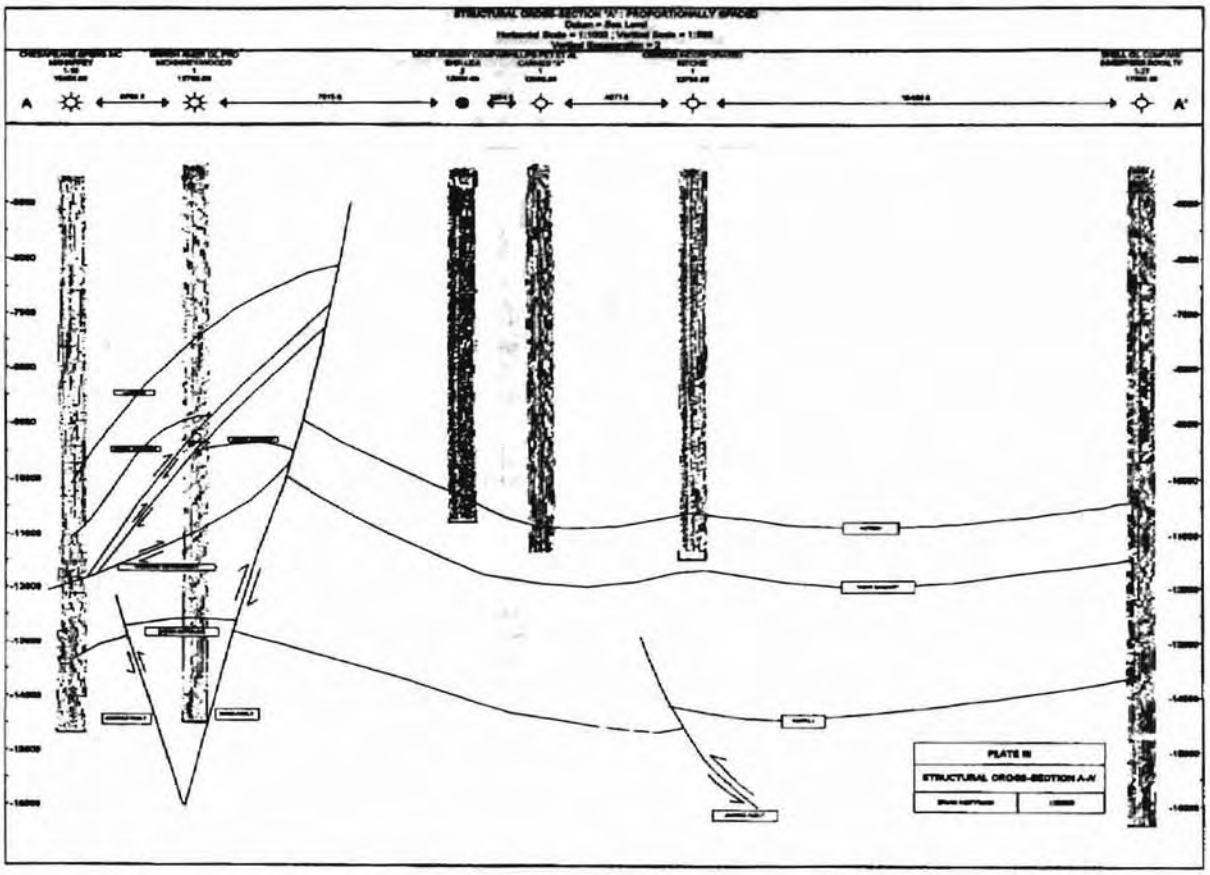

Figure 17. Structural cross-section A-A' for quick reference only. The reader is directed to Plate III for better detail.

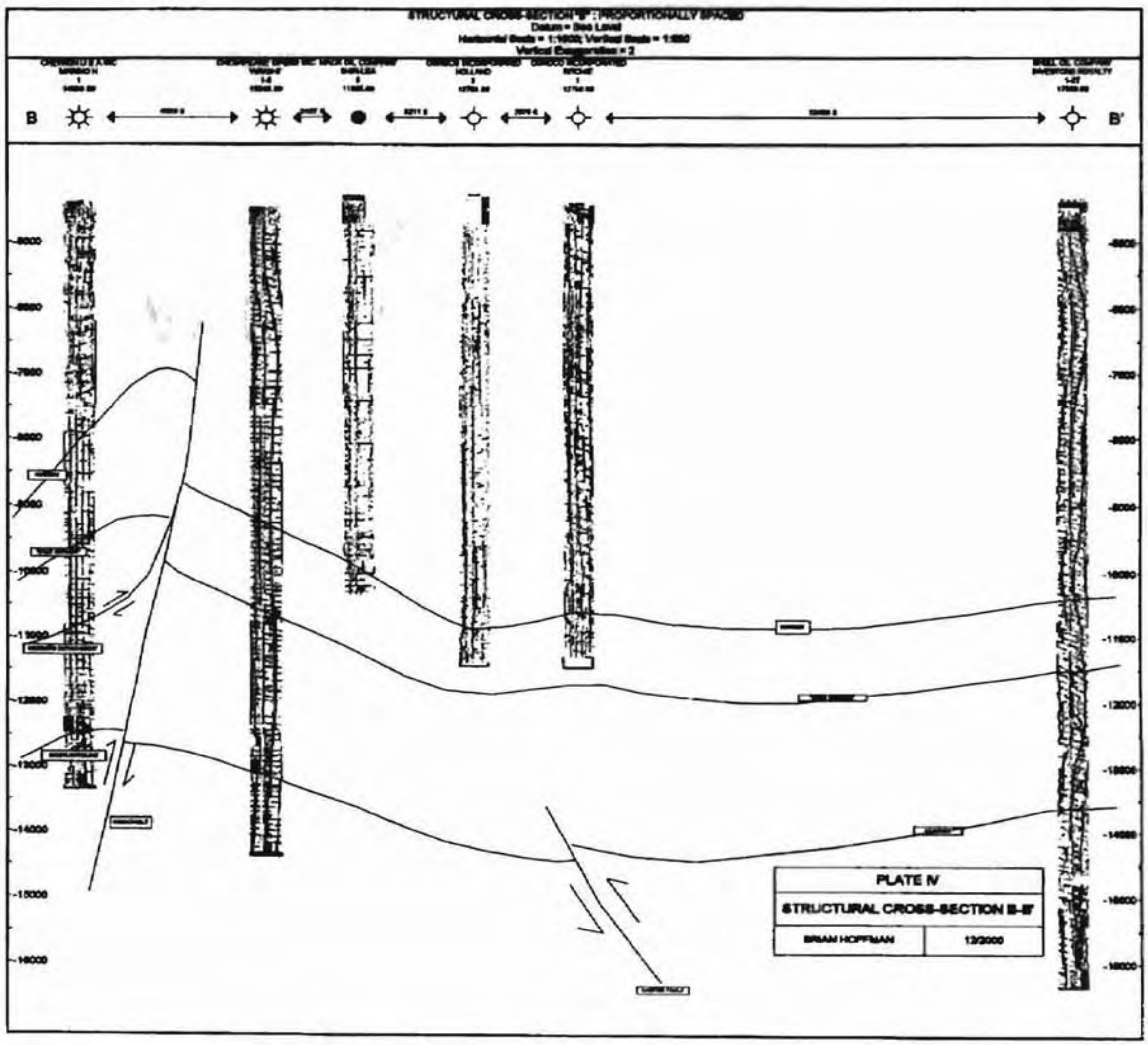

Figure 18. Structural cross-section B-B' for quick reference only. The reader is directed to Plate IV for better detail.

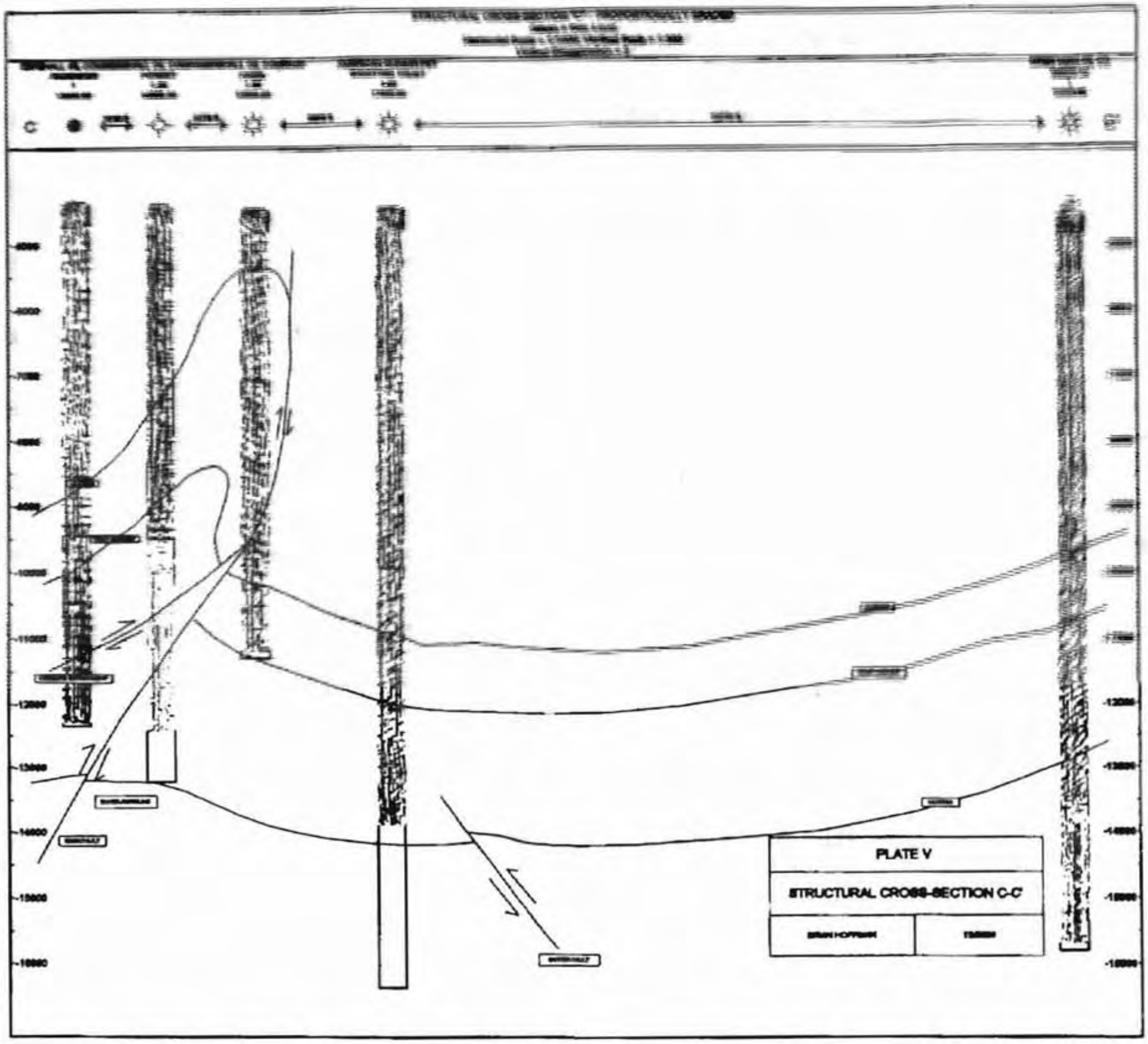

Figure 19. Structural cross-section C-C' for quick reference only. The reader is directed to Plate V for better detail.

On the western half of the line however, the Hutson is dipping fairly steeply to the southwest. The Hunton also dips to the southwest but shallower. Toward the center of the seismic line, continuity of the Hutson is lost due to the steeper bed dips and faulting. The interval thickness between the Hutson and Hunton is also thickened toward the center of the seismic line. This is due to the Goddard Detachment, which on this line, is difficult to see. However, on the 3-D data viewed at the Marathon office, the Goddard Detachment surface and multiple other splay faults of the detachment could be distinguished easily in the core of the structure. The 3-D data is proprietary to Marathon and not available for publishing. The Hunton can be seen "rolling over" on the Baker Anticline with several faults piercing the event. The Knox fault can be seen on the northeastern limb of the anticline dipping steeply to the southwest with reverse separation connecting up to the Goddard Detachment in the Pennsylvanian section. A second unnamed fault with reverse separation and dipping to the southwest also pierces the Hunton but not the Pennsylvanian section on the northeastern limb of the anticline. The Carter fault can be seen on the extreme northeastern limb of the Baker Anticline. It marks the transition point from the flat-lying to the northeast and the onset of upturned beds into the structure. It shows reverse separation and dips to the northeast.

The second seismic line, also perpendicular to the Knox structure and parallel to cross-section C-C' (Plate V), is in the middle part of the area. Figure 28 (Plate XIII) shows the uninterpreted version and Figure 29 (Plate XIV) shows the interpreted line. Although this line exhibits more vertical exaggeration, the flat-lying Hutson and Hunton can still be seen northeast of the structure. As on the previous line, the Hutson dips to the southwest and crests in the middle of the seismic line. Thickening from the Goddard Detachment between the Hutson and Hunton is still visible in the core of the structure.

The Goddard Detachment position proves to be elusive on this line as well and so was interpreted from the 3-D data at the Marathon office. The Knox fault dips steeply to the southwest on the northeastern side of the Baker Anticline, breaking the Hunton and joining with the Goddard Detachment in the Pennsylvanian section. It exhibits reverse separation. The Carter fault as well, exhibits reverse separation and disrupts the Hunton, but none shallower, on the northeastern side of the Baker Anticline. It dips northeastward and marks the transition point of the flat-lying beds and the beginning of the upturned beds in the structure.

The third seismic line is perpendicular to the structure as well, but crosses the northern section of the Carter-Knox structure. No cross-section lines are parallel to it. Figures 30 (Plate XV) and 31 (Plate XVI) show the interpreted and uninterpreted seismic lines, respectively. The Carter-Knox structural relief is substantially less across this line. The Baker Anticline is visible on the southwest side of the seismic line. The Hutson and Hunton are roughly parallel with only a small thickening of the structure's core. The Goddard Detachment is still not visible and is interpreted from the 3-D data. The Knox fault dips southwestward piercing the Hunton and joining the Goddard Detachment in the Pennsylvanian section, but the dip on the fault is substantially less than in the southern portion of the Carter-Knox structure. The Knox fault is splintered into several splays showing reverse separation in the Hutson section, including several antithetic faults that dip to the northeast. The Carter fault is on the northeastern side of the Baker Anticline, dipping to the northeast and showing reverse separation.

The fourth seismic line parallels the strike of the structure, cutting across it at the midpoint. Cross-section F-F' (Plate VIII) parallels it. Figures 32 (Plate XVII) and 33 (Plate XVIII) show the interpreted and uninterpreted seismic lines, respectively. The

Baker Anticline can be seen exhibiting only slight relief, since the seismic line parallels the crest. The Goddard Detachment can be seen remarkably well dipping to the northwest and thrusting the Hutson section over itself. The Hunton shows several reverse-fault-cored anticlinal features. All faults in these anticlines dip to the southeast.

Baker Anticline

The Baker Anticline extends the length of the Carter-Knox structure (Figures 17-33, Plates III-XVII). The Caney, Sycamore, Woodford, Hunton, Sylvan, and Viola marker beds are the only strata that are deformed in the anticline. Formation of the anticline may have pre-dated formation of the Carter-Knox structure. Perkins (1997) and Reedy (1968) observed thinning of the Hunton on the crest of the anticline which suggests Silurian formation of the anticline with post-Hunton unconformity. From well-log and seismic data, no thinning of crestal strata on the anticline is observed in the study area. No faults were observed in the Hunton from well log data, due to the steepness of the faults. However, all seismic lines showed faults penetrating the northeastern limb of the anticline. At the southern end of the study area, the anticline is faulted by the Knox and Brickle faults. The remainder of the anticline in the study area is faulted only by the Knox fault.

Knox Fault

The main fault extending through the Carter-Knox structure is the Knox fault. It dips to the southwest, exhibits reverse throw, and is interpreted as the master fault in a positive flower structure. Although no wells penetrate the fault plane of the Knox fault without the Goddard Detachment, both 2-D and 3-D seismic data confirm its presence.

In the southern portion of the study area, the available 2-D and 3-D seismic data show a steep, southwest-dipping fault with reverse separation cutting all strata to basement (Figures 26-29, Plates XI-XIV). Toward the northern end of the study area, the Knox fault decreases in dip and does not appear to cut above the Pennsylvanian section (Figures 30-31, Plates XV-XVI).

Where possible, cross-sections were constructed parallel to seismic lines to aid in the interpretation of the structure. Also, cross-sections were constructed perpendicular to dip, where possible, to avoid apparent dip complications and consequent falsehoods.

Six cross-sections (Figures 17-22, Plates III-VIII) show the Knox fault, combined with the Goddard Detachment, extending the length of the Carter-Knox structure. In the southern portion of the study area, approximately 5,000 feet of reverse separation is observed in the Pennsylvanian strata (Figure 17, Plate III). On the northern cross-sections (Figures 19-20, Plates V-VI), the amount of reverse separation on the Knox fault, combined with the Goddard Detachment, diminishes. The amount of reverse separation decreases to approximately 50 feet.

Two structural contour maps were constructed using the tops of the Hutson and Hunton Group. The structure map using the top of the Hutson formation is representative of the Pennsylvanian section (Figure 23 and Plate IX). The structure map using the top of the Hunton is representative of the Devonian and older strata (Figure 24 and Plate X). Seismic lines and available well data aided in placement of faults on the structure maps. The Knox fault cuts through both the Hutson and Hunton Group (Figures 23 and 24) on their respective structural contour maps, trending in a straight line northwestward. The linear appearance of the Knox fault in map view on the structural contour maps fits the criteria for being a master fault.

Brickle Fault

The Brickle fault is not seen on any seismic lines but is inferred on cross-section

A-A' (Figure 17, Plate III). It is southwest of the Knox fault. With no wells penetrating its fault plane, the Brickle fault is inferred because of the relief differences between the Mahaffey 1-19 in Sec.19, T.3N., R.5W., and the McKinney Woods #1 in Sec. 17, T.3N., R.5W. Also, Perkins (1997) interpreted the Brickle fault as trending between the previous two wells. It is interpreted as an antithetic fault of the Knox fault because it dips to the northeast and shows approximately 200 feet of reverse separation in the southern portion of the structure. There is no evidence from well data or seismic lines, for it to trend northward from this location.

Carter Fault

The Carter fault exhibits reverse separation and dips to the northeast. It lies to the northeast of the Knox fault. No wells penetrate its fault plane. However, it is seen on the seismic lines (Figures 26-31, Plates XI-XVI). The Pennsylvanian section is unaffected by it. Displacement is limited only to Devonian strata and below. Unlike the Brickle fault, the Carter extends the length of the Carter-Knox structure.

Goddard Detachment

Another outstanding structural feature of the study area is the Goddard Detachment. It accounts for most of the reverse separation (3,000 feet in some places) and shale thickening found within the Carter-Knox structure. The Goddard Detachment originates in the bedding planes of the Goddard Shale, which is between the Hutson formation and Caney formation. The detachment is formed on the southwest side of the structure. It creates wedges of shale as it ramps up over more competent beds to the northeast where it is bounded by the Knox fault. Inside this wedge, shale packages stack upon one another accounting for the increased thickness of shale near the center of the structure. This thickening of shale that contains some marker beds is the only feature that can be seen in well logs and on seismic lines. Since the fault plane is parallel to the bedding planes, it proves to be an elusive event on 2-D seismic. However, the 3-D seismic data exhibited the detachment and smaller splays within it quite well. From the 3-D data, a basal detachment, a roof thrust, and multiple smaller splay faults are observed and interpreted on to the southern seismic line (Figure 27, Plate XI). Wells that penetrate this area of the detachment exhibit the stacking of key beds. One of these key beds is the "boat marker". The B. A. McKinney-Woods well (Sec. 17, T.3N., R.5W.) has three "boat markers" stacked one on top of each other. The B. A. Teter well (Sec. 18, T.3N., R.5W.) has two stacked "boat markers"(Figure 25).

The cross-sections constructed using well data and seismic lines show the stacking and overturning of key beds along the Carter-Knox structure. The southern end of the study area exhibits severe thrust faulting within the Goddard Shale from the Goddard Detachment. Cross-section A-A' (Figure 17, Plate III) shows multiple repetitions of the "boat marker" within 700 feet of stratigraphic interval. Toward the northern end to the structure, repetition of beds within the Goddard Shale has yielded to overturned beds. The overturning of beds on cross-section C-C' (Figure 19, Plate V) continues through cross-section D-D' (Figure 20, Plate VI). The Godwin 1-14 in Sec. 14, T.4N., R.6W., is interpreted as having overturned Goddard Shale beds.

All the data, when brought together and analyzed portray the characteristics of a wrench-fault system with a positive flower structure. Reedy and Sykes' (1958) interpretation of a fold-thrust belt is probably inaccurate. However, considering that they only had well data and the understanding of strike-slip faulting was in its infancy in the 1950's, they had done remarkable work in the area.

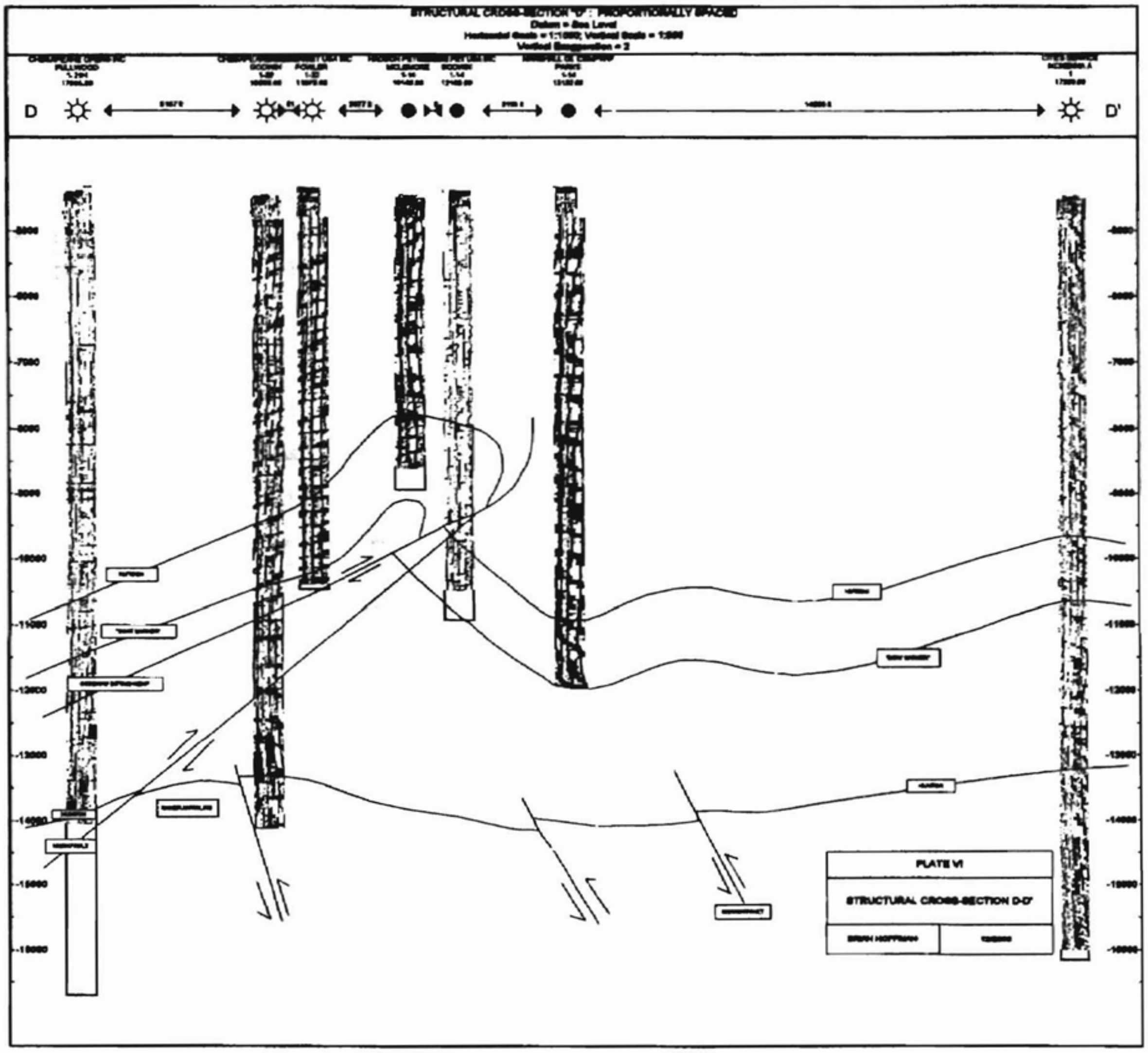

Figure 20. Structural cross-section D-D' for quick reference only. The reader is directed to PlateVI for better detail.

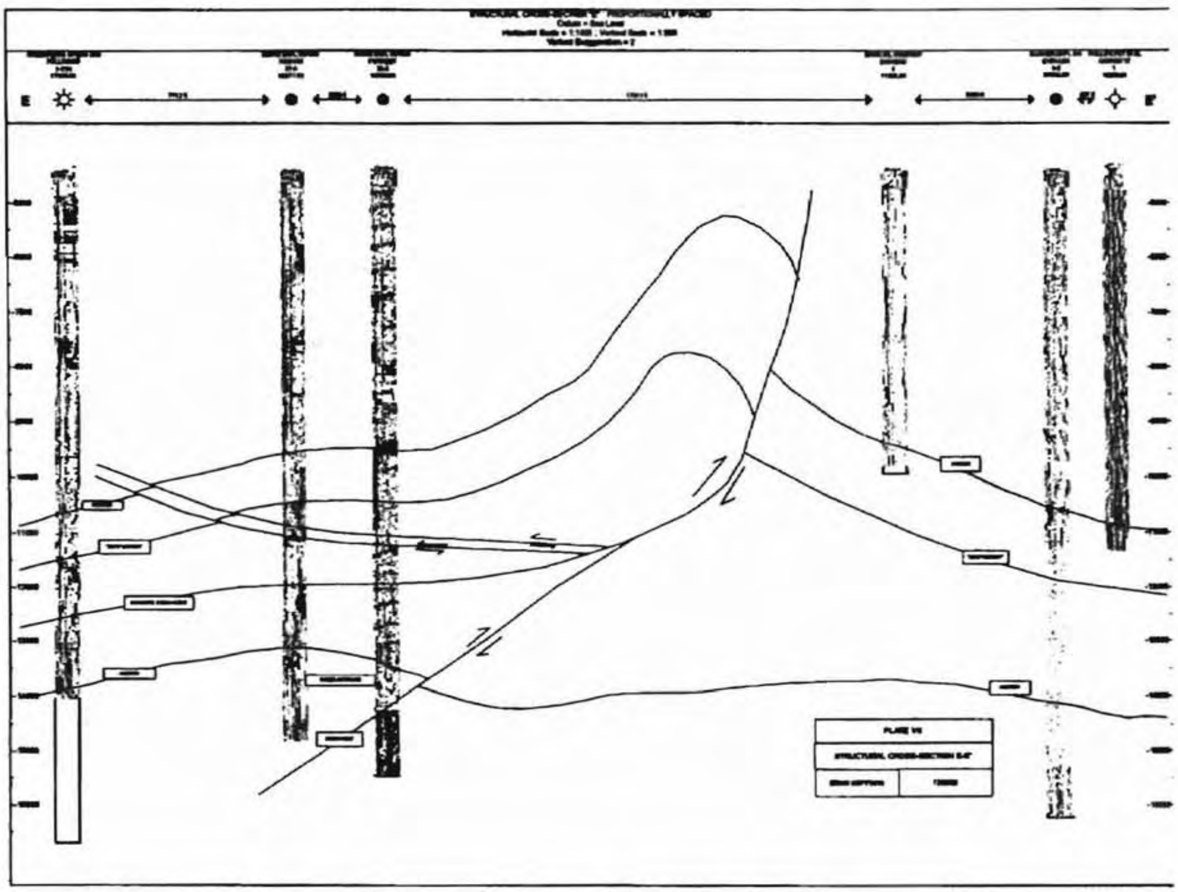

Figure 21. Structural cross-section E-E' for quick reference only. The reader is directed to PlateVII for better detail.

A fold-thrust belt would show a series of parallel reverse faults with near constant separation stacking upon each other (Figure 34). These stacked sheets would join each other at common near-vertical faults perpendicular to strikes of the thrust sheets. A common parallel basal detachment fault is also associated with fold-thrust belts. The Knox and other faults in the Carter-Knox area lose separation and flatten toward the northern end of the structure, but not at depth, as would be if the structure were a well-developed fold-thrust belt type thrusting.

McCaskill (1998) studied thickness differences across a fault in Devonian and older strata to the south of the Carter-Knox field. He concluded that the major thickness differences across the Eola fault could be attributed only to a left-lateral strike-slip fault trending eastward. The southern end of the Carter-Knox intersects the Eola fault where 16 mi. (26km) of left-lateral displacement is interpreted. This large displacement appears to be the major influence in the formation of the Carter-Knox feature. The geometry of associated deformations along a major strike-slip fault can be predicted using the strain ellipse. The predicted geometry of wrench faults and en-echelon folds can be seen on Figure 35. The Knox fault lines up exactly where it should, as well as do the en-echelon folds. At the southern end of the Carter-Knox structure, closest to the Eola fault, faulting and deformation of strata are most extreme. Northward, away from the source of deformation, faulting and folding are less pronounced. This also suggests a genetic relationship between the Eola fault and the Carter-Knox structure.

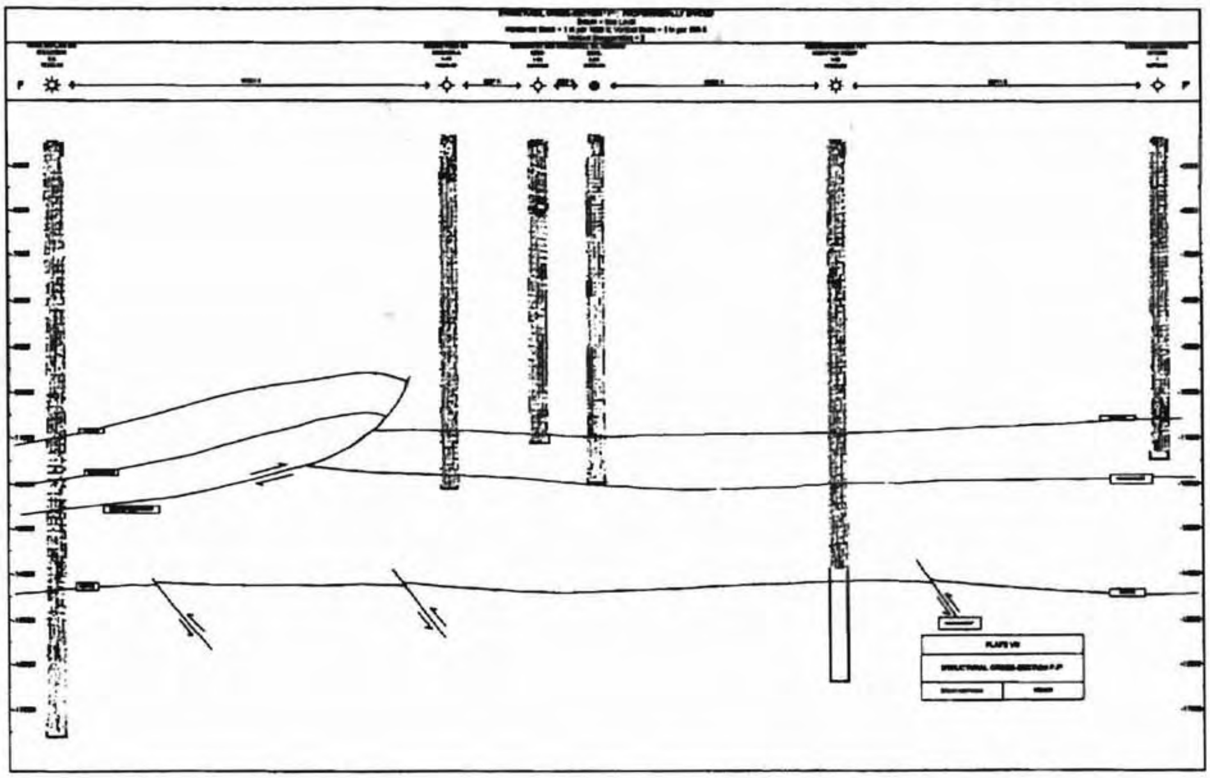

Figure 22. Structural cross-section F-F' for quick reference only. The reader is directed to Plate VIII for better detail.

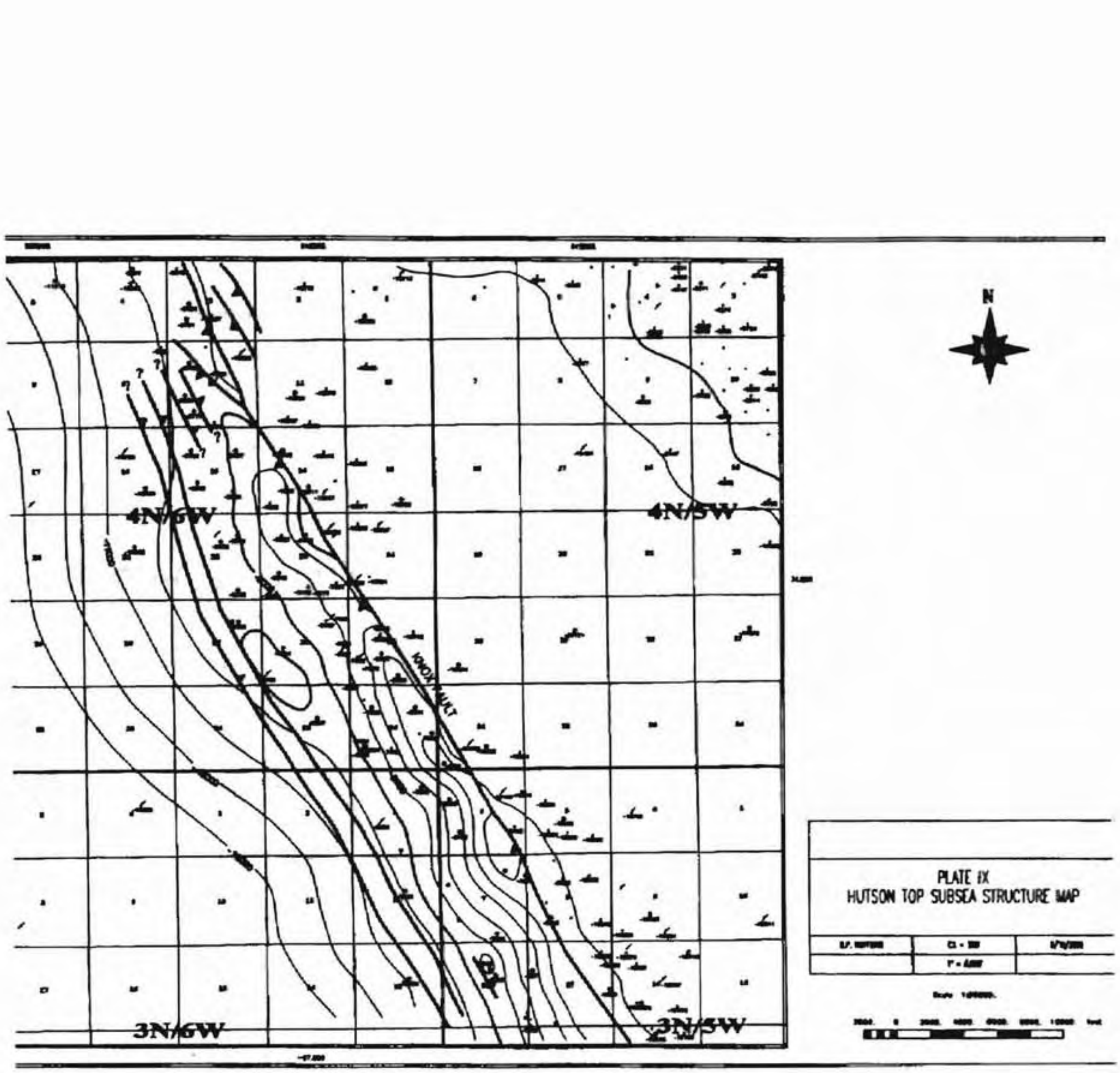

Figure 23. Structural contour map using the top of the Hutson.

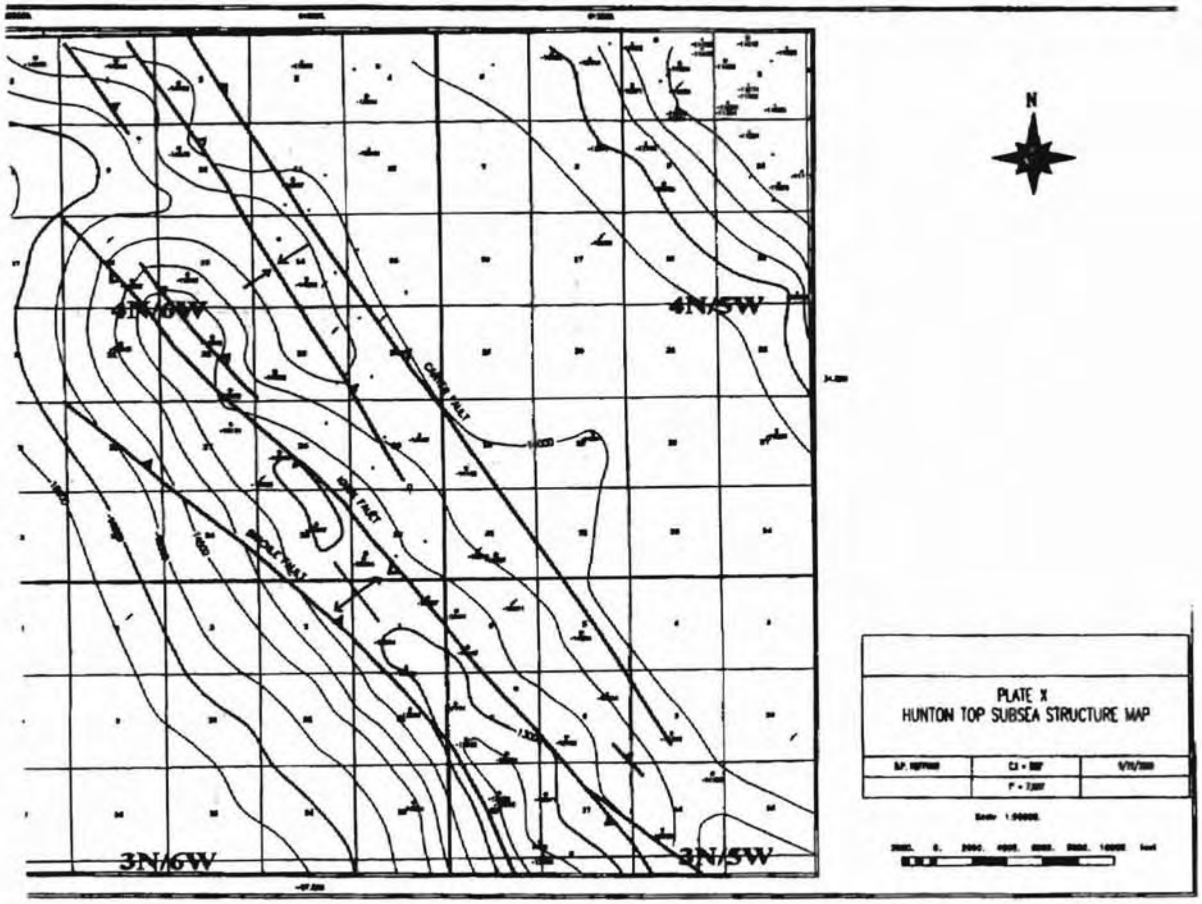

Figure 24. Structural contour map using the top of the Hunton.

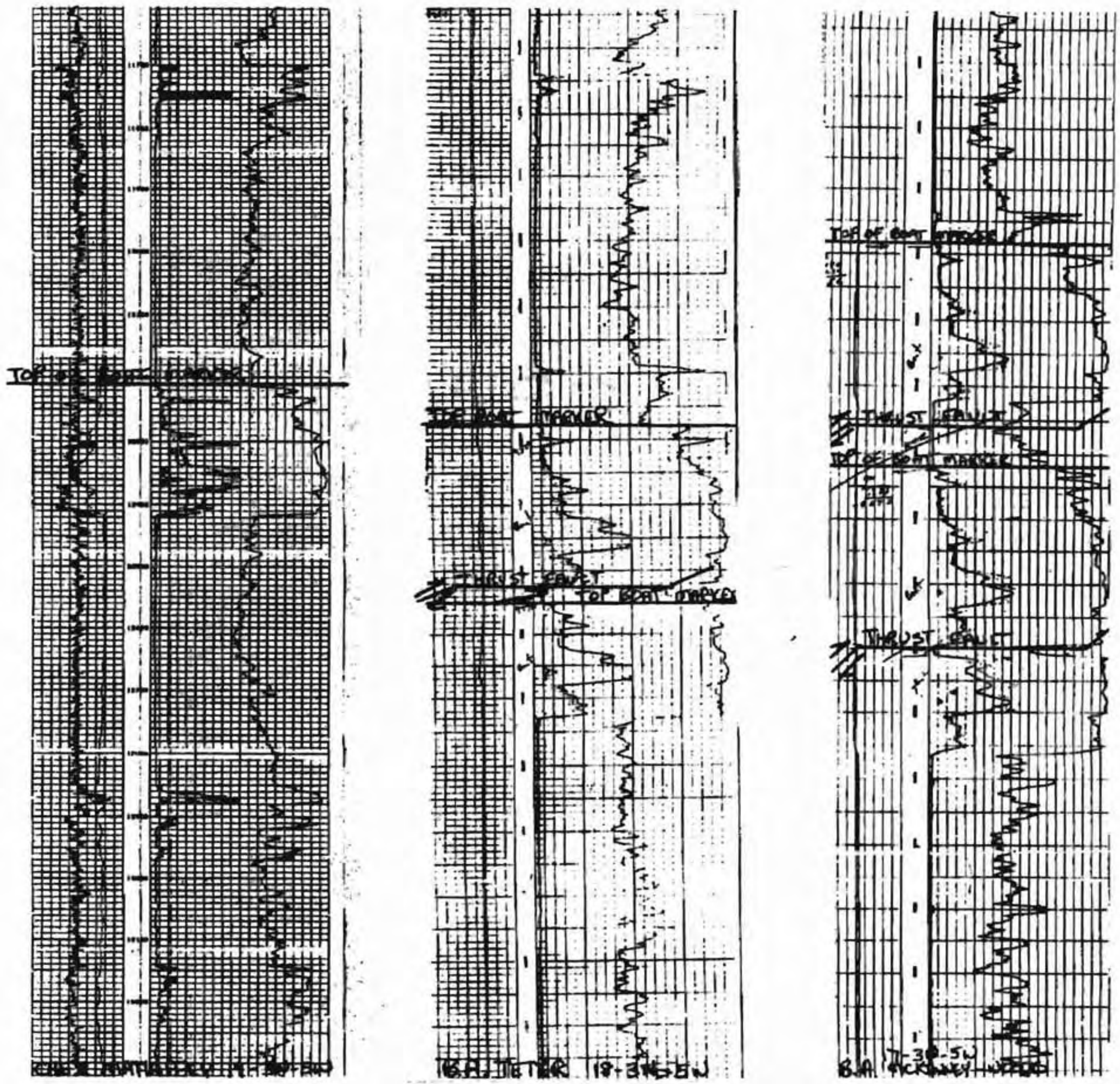

Figure 25. Well logs showing stacked "boat marker" beds.

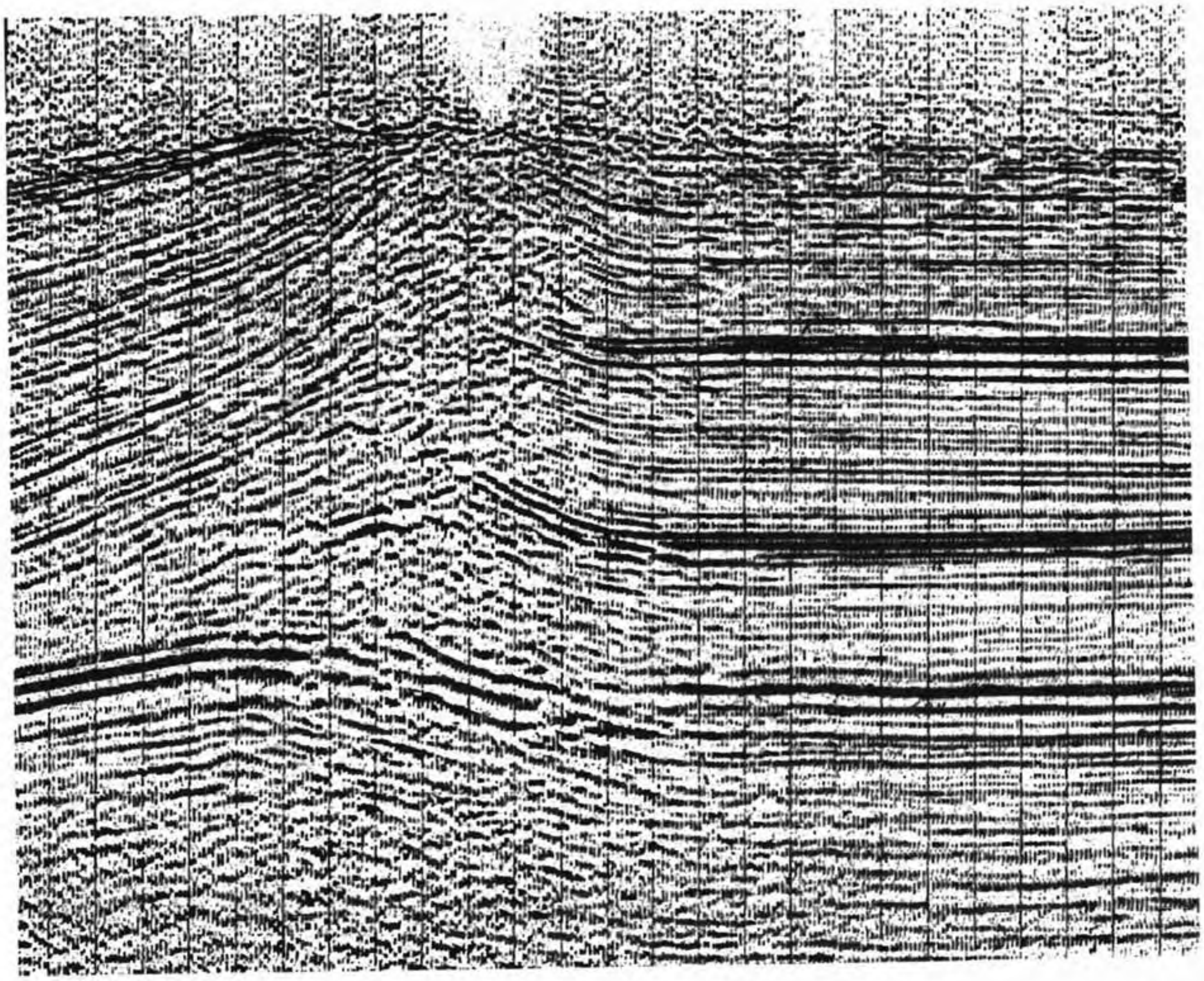

Figure 26. Uninterpreted southern seismic line. The reader is directed to Plate XI for better detail.

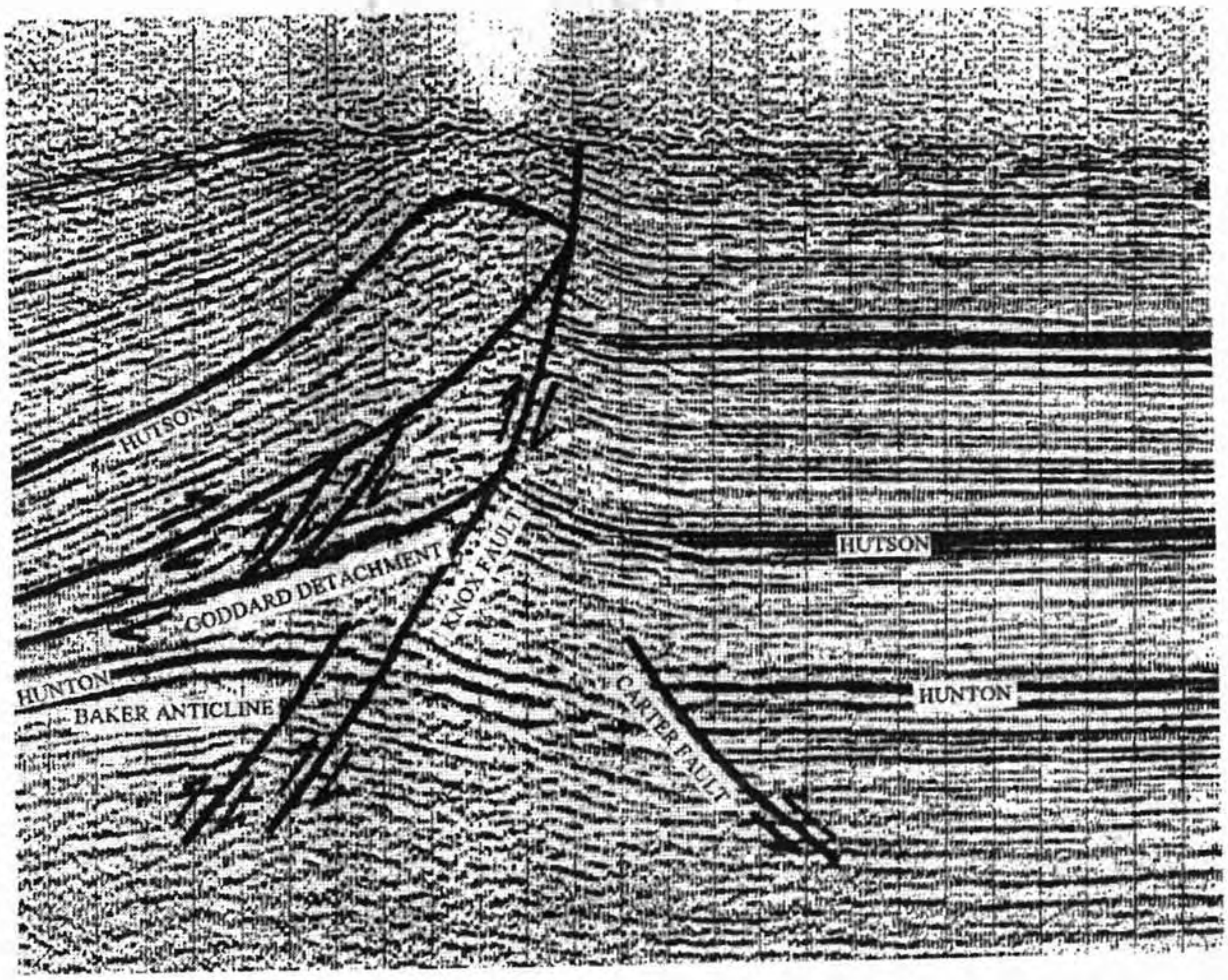

Figure 27. Interpreted southern seismic line. The reader is directed to Plate XII for better detail.

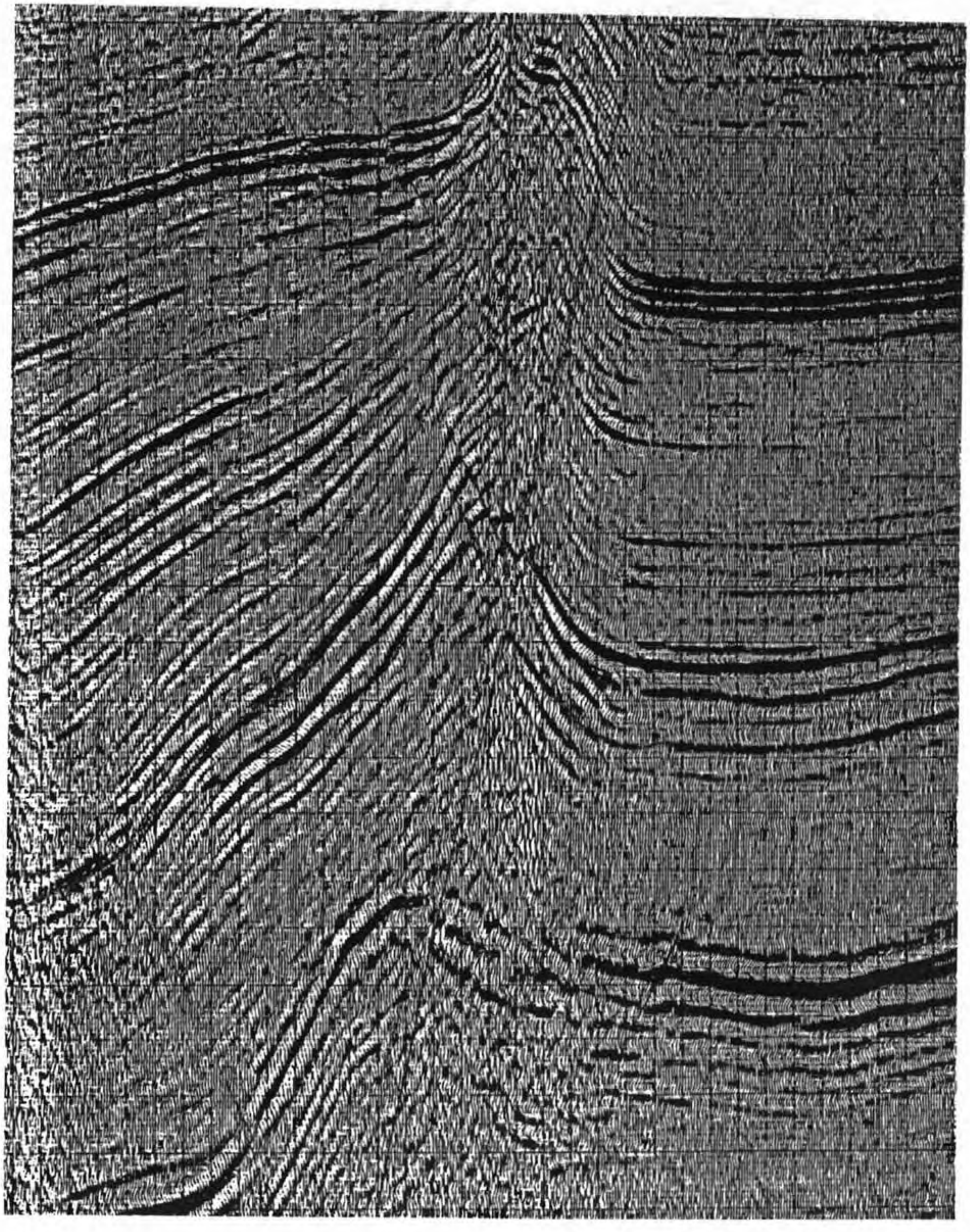

Figure 28. Uninterpreted middle seismic line. The reader is directed to Plate XIII for better detail.

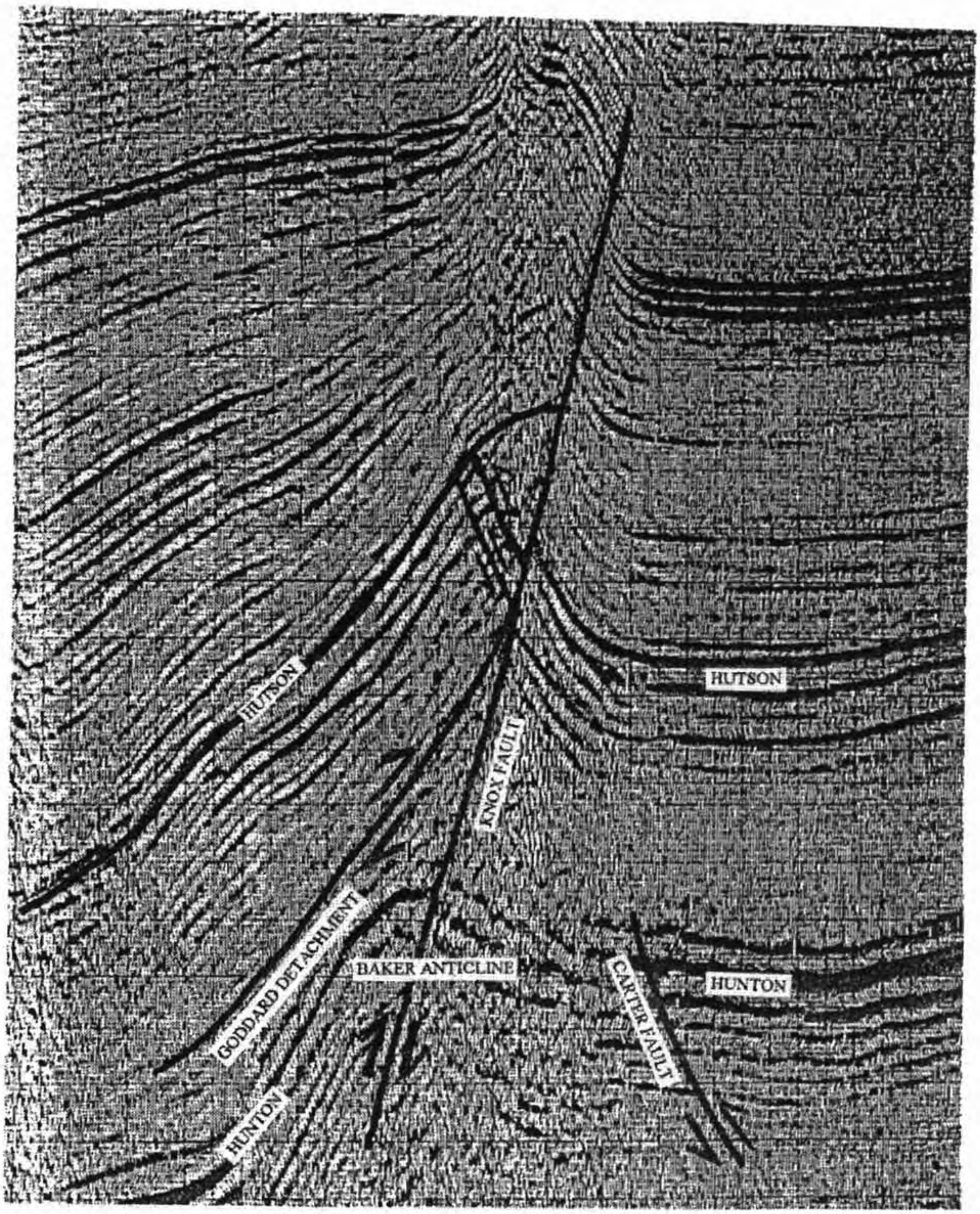

Figure 29. Interpreted middle seismic line. The reader is directed to Plate XIV for better detail.

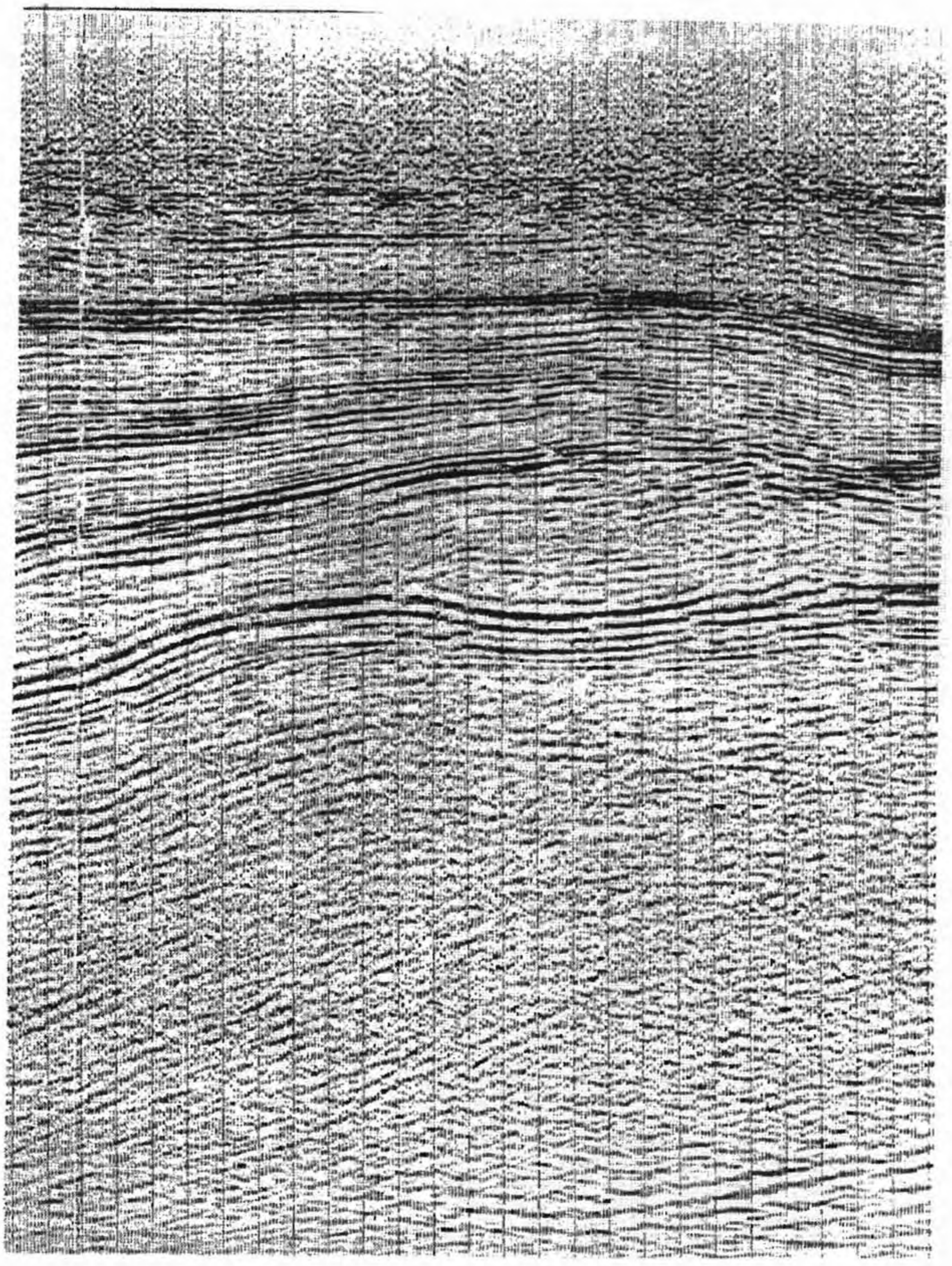

Figure 30. Uninterpreted northern seismic line. The reader is directed to Plate XV for better detail.

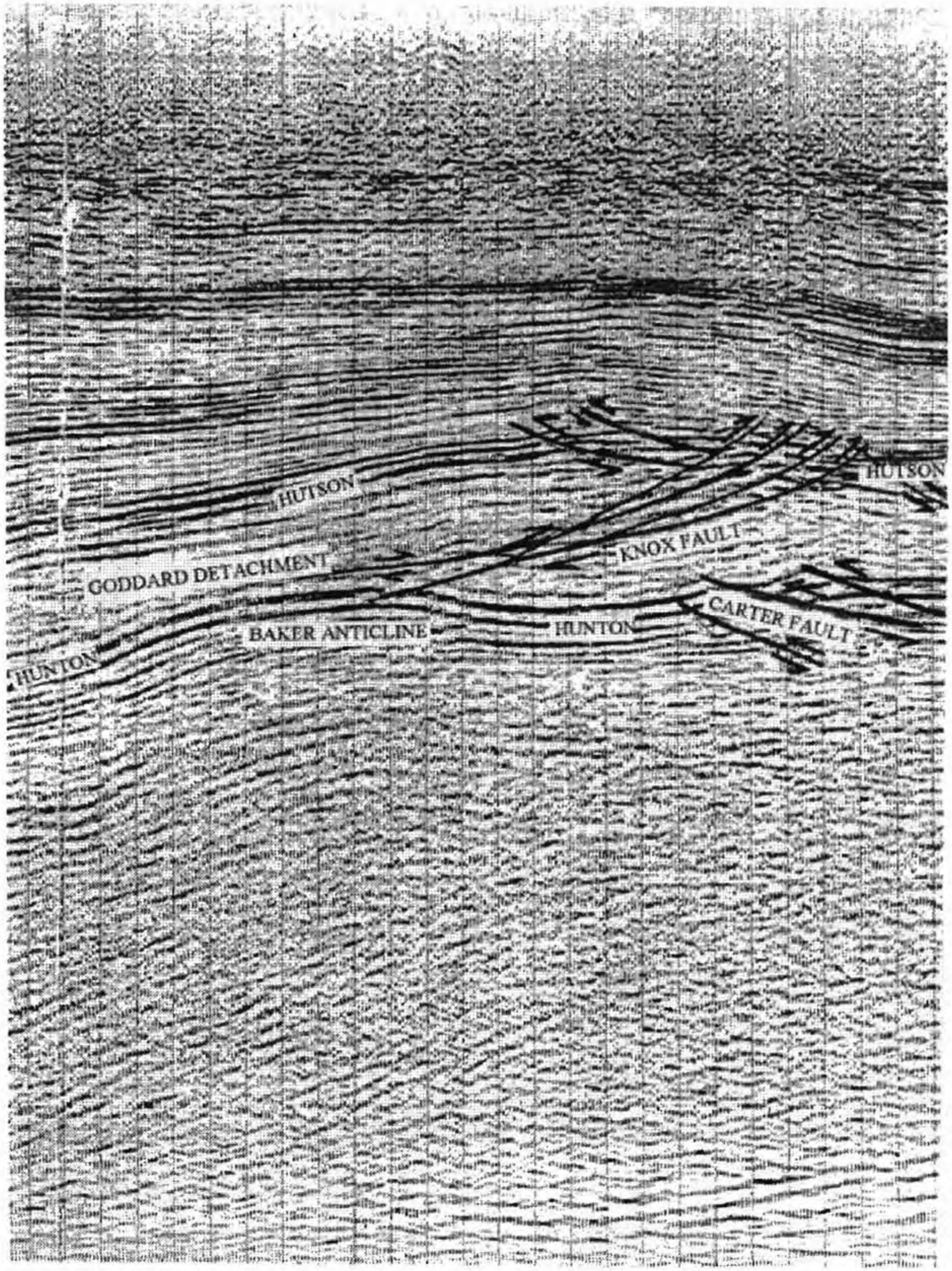

Figure 31. Interpreted northern seismic line. The reader is directed to Plate XVI for better detail.

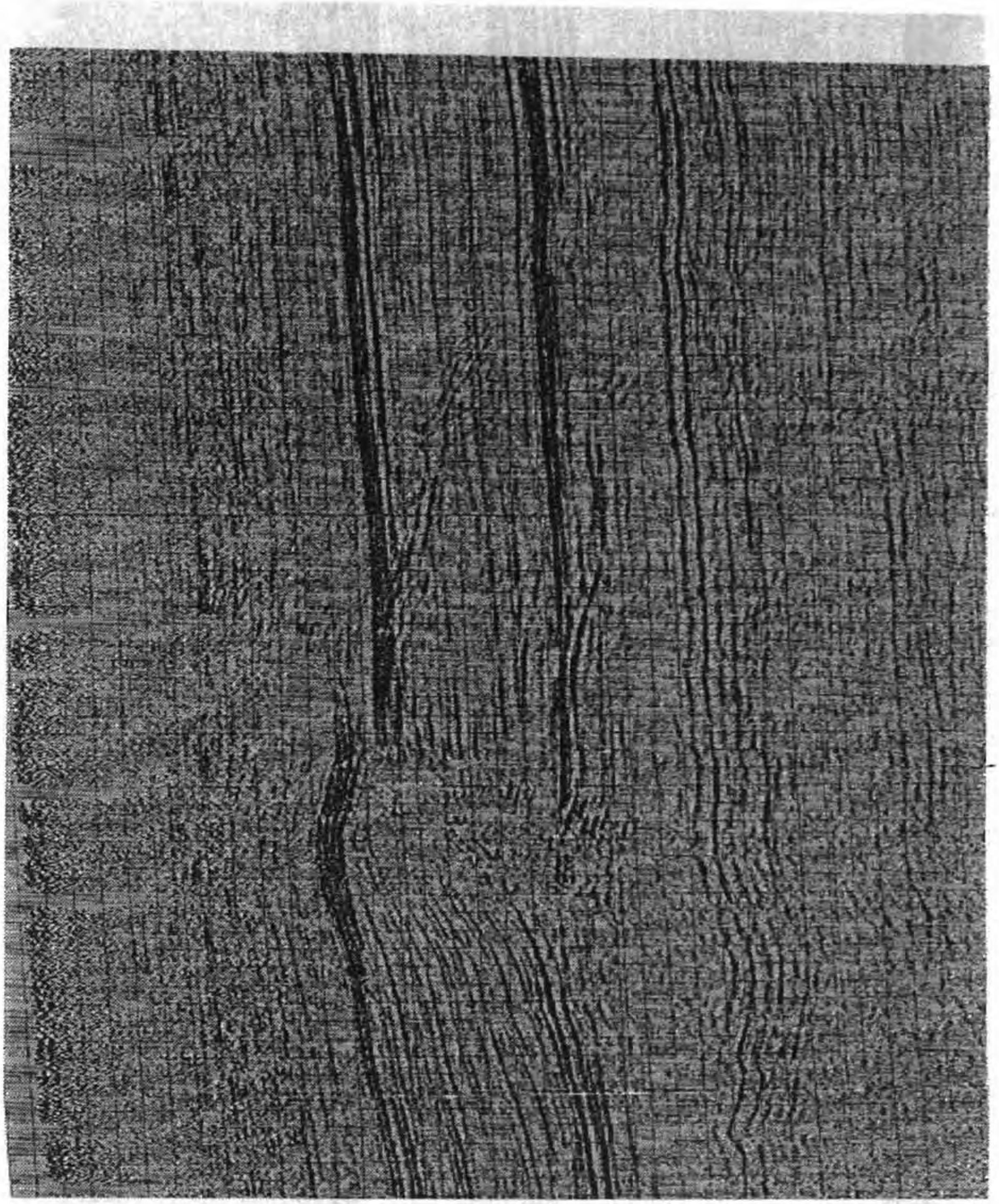

Figure 32. Uninterpreted seismic line parallel to strike. The reader is directed to Plate XVII for better detail.

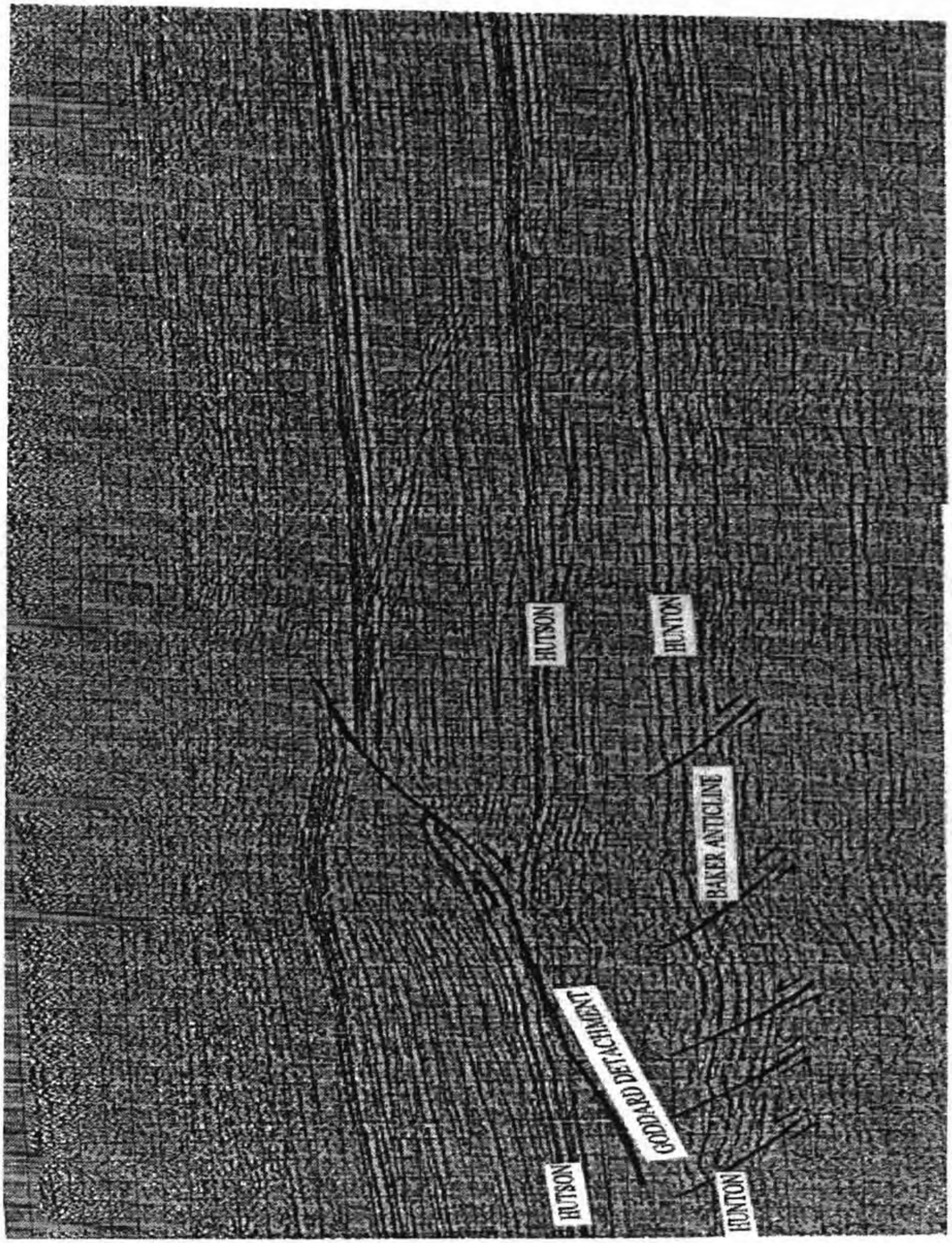

Figure 33. Interpreted seismic line parallel to strike. The reader is directed to Plate XVIII for better detail.

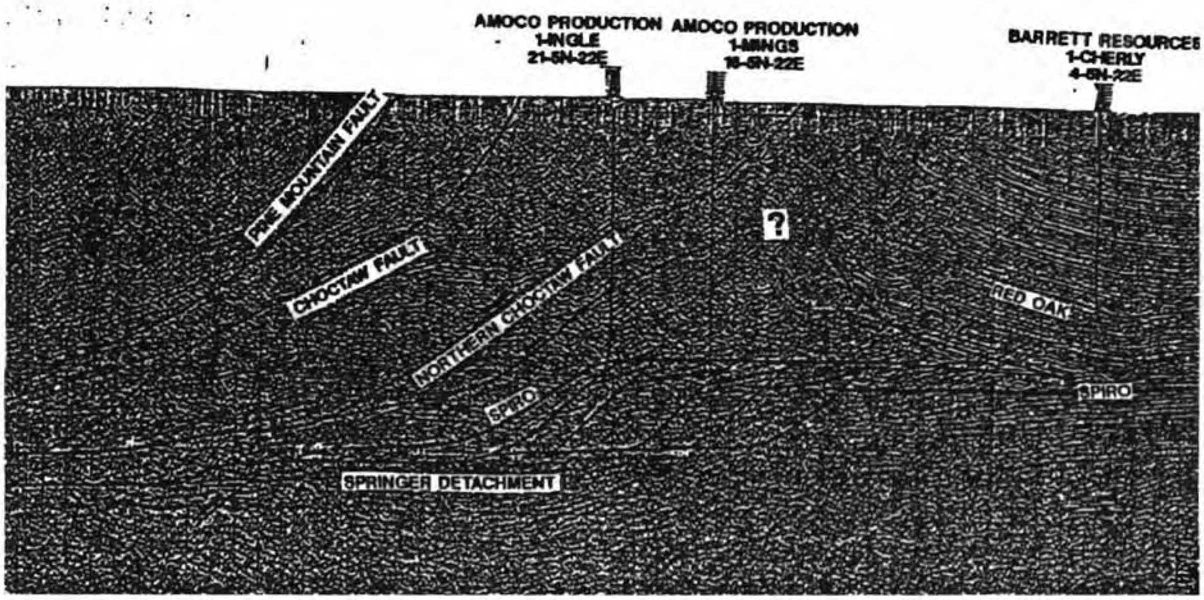

Figure 34. Seismic line showing stacked thrust sheets of a fold-thrust belt from Ronk, (1997).

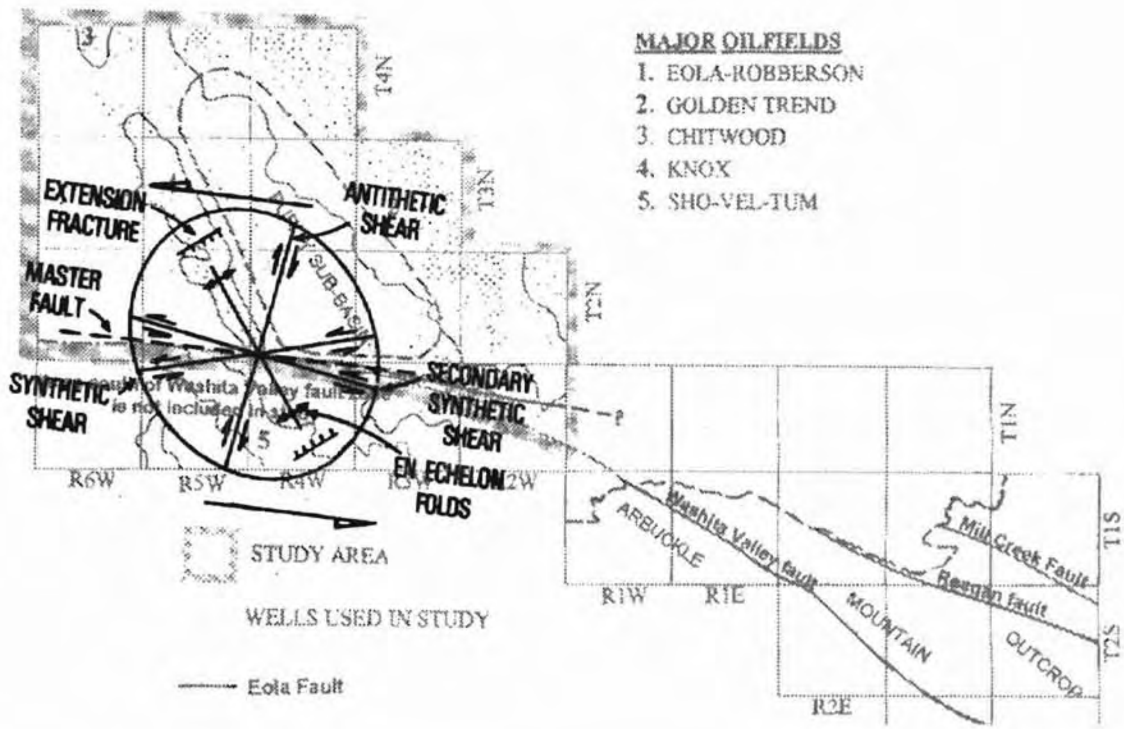

Figure 35. Strain ellipse showing predictable geometries of the study area (from McCaskill, 1998).

CHAPTER V

STRUCTURAL EVOLUTION OF THE CARTER-KNOX AREA

It appears little deformation was placed on the Anadarko Basin after the initial phases of rifting ceased in the Cambrian. Normal faulting may have been prevalent throughout the area with the subsidence of the basin from Late Cambrian to Mississippian.

Until after the Hunton was deposited, no significant event of deformation occurred. Perkins (1997) and Reedy (1968) interpreted a thinning of the Hunton on top of the Baker Anticline indicating that uplift and erosion had occurred immediately after Hunton deposition. The Baker Anticline would therefore have been one of the first features formed in the Carter-Knox around Late Devonian.

Compressional forces in the Anadarko Basin, according to Perry (1988), came about during the Late Mississippian to Early Pennsylvanian as North and South America collided with each other, closing off the proto-Atlantic Ocean. With continued convergence of the two plates, transpressional forces began to dominate during the Late Pennsylvanian, creating much of the strike-slip faulting in the area surrounding the Carter-Knox field. Large displacements along these faults, as much as 40 mi. (64 km.) on the Eola fault (McCaskill, 1998) in some areas, faulted and folded the strata. Movement along the Eola fault probably contributed substantially to formation of the Knox, Brickle, Carter, and other faults extending into the Carter-Knox field as structural features that showed reverse separation. Older normal faults may have become reactivated at this time.

The more competent beds of pre-Devonian time faulted and folded only slightly under the compressional forces, creating a series of en-echelon folds throughout the area. These en-echelon folds may be cored by reverse faults. Large displacements on some of the faults, including the Knox fault, are limited to the area immediately around the Eola fault. The increasing stresses were accommodated in the Springer sections. Folds in the Springer section parallel folds in the Hunton in most places on the flanks of the Carter-Knox field. However, a narrow band of intensely deformed strata in the Springer section was created when the Goddard Detachment formed parallel to bedding planes and began to ramp up, cutting across zones of weakness. All the transpressional forces near the Eola fault were focused in the area of the Carter-Knox field, creating a fault propagation fold. The area closest to the Eola fault allowed the Goddard Detachment to ramp up a fairly steep dip. This accounts for the multiple reverse faults in the area, which would accommodate the transpression. Farther away from the Eola fault, the Goddard Detachment began to flatten out because the compressional forces created by the left-lateral movement on the Eola fault were dying out northward. Since there was a lack of transpressional forces to fracture folded strata in the northern part of the Carter-Knox field, overturned beds now dominate the low-dip-angle detachment surface. Finally, at the extreme northern end of the Carter-Knox, many small displacement reverse faults accommodate the transpression.

CHAPTER VI

CONCLUSIONS

From the well data and the seismic lines, the Carter-Knox structure has been interpreted as a positive flower structure formed during Pennsylvanian left-lateral strike-slip faulting. By placing the strain ellipse diagram for a left-lateral fault over the main Eola/Washita Valley fault, compressional stress features in the area of the Carter-Knox structure can be interpreted. The Carter-Knox oil field fits perfectly into the predictable pattern of where antiforms and faults of positive flower structures should be. From this the following can be concluded:

1) The Knox fault exhibits itself as a large antithetic splay fault to the Eola/Washita Valley fault system.

2) The Knox fault is a master fault of the structure.

3) The Brickle fault is a splay of the Knox fault.

4) The Goddard detachment accounts for the thickening of shales in the core of the structure due to the compressional forces.

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APPENDIX

Well log data sheets

Operator	Well	Township	Range	Section	Location	Field	KB	GL	County	Top Hutson	Top Hunt.
Conoco	Ritchie #1	3N	5W	4	2640' FNL 1320' FWL	N. Purdy	1288	1268	Grady	-10,792	N/A
Conoco	Holland 5 #3	3N	5W	5	1320' FSL 1320 FEL	N. Purdy	1295	1273	Grady	-10,830	N/A
Conoco	Holland 5 #4	3N	5W	5	1453' FSL 1458' FWL SW/4	N. Purdy	1274	1251	Grady	-10,201	N/A
Conoco	Holland #2	3N	5W	5	C-S/2-NW/4	N. Purdy	1260	1238	Grady	-10,662	N/A
Chesapeake Oper.	Jerry #1-5	3N	5W	5	NW-SE-NE-NE-SW	Carter-Knox	1240	1218	Grady	-10,670	-14,200
Conoco	Holland 5 #1	3N	5W	5	1320' FSL 2840' FEL	N. Purdy	1270	1247	Grady	-10,560	N/A
Mack Oil Co.	Bowers #1	3N	5W	6	S/2-NE-SE	Knox Cox City	1270	1258	Grady	-9,440	N/A
Chaparral Energy	Hefner #1-6	3N	5W	6	NE	Carter-Knox	1225	1206	Grady	-10,375	N/A
Chesapeake Oper.	Holland #1-6	3N	5W	6	SE-SE-NW-SW	Carter-Knox	1277	1251	Grady	-8,193	N/A
Chesapeake Oper.	Presidio #1-6	3N	5W	6	S/2-N/2-SW-NW	Carter-Knox	1302	1280	Grady	-6,693	N/A
Marathon Oil Co.	Hefner #1-6	3N	5W	6	1320' FNL 1320' FEL	Carter-Knox	1251	1223	Grady	-10,139	-13,671
Chevron USA	Jerry Bell #3	3N	5W	7	550' FSL 810FWL	Carter-Knox	1279	1252	Grady	-7,241	-12,551
Mack Oil Co.	Shir Lea #3	3N	5W	8	1160' FSL 2280' FWL NW/4	Cox City	1279	1264	Grady	-9,921	N/A
Bunker Exploration	Shir Lea #1-8	3N	5W	8	C-NE	Cox City	1286	1264	Grady	-10,519	-14,084
Chesapeake Oper.	Wright #1-8	3N	5W	8	E/2-SW-SW-NE-SW	Carter-Knox	1268	1247	Grady	-9,262	-13,122
Mack Oil Co.	Shir Lea #4	3N	5W	8	NW-NW-SE	Cox City	1276	1256	Grady	-9,924	N/A
Slawson	Garretson	3N	5W	9	C-SW-SE	N. Purdy	1213	1198	Grady	-10,867	N/A
Mack Oil Co.	Crabb #1	3N	5W	9	C-SW-SW	Knox	1241	1229	Grady	-10,658	N/A
Chesapeake Oper.	Ball #1-9	3N	5W	9	1650' FSL 2310' FWL	Carter-Knox	1240	1217	Grady	-10,965	-14,345
Phillips Petr. Co.	Carnes A#1	3N	5W	9	C-SW-NW	West Cox City	1254	1236	Grady	-10,871	N/A
Mack Oil Co.	Howell #1	3N	5W	16	NE-SW-SE	Knox	1159	1142	Grady	-10,901	N/A
Mack Oil Co.	Phipps #1	3N	5W	16	NE-SW	Knox	1225	1211	Grady	-10,235	N/A
Donald C. Slawson	Nicholson #1-16	3N	5W	16	430' FWL 330 FSL of NE	Cox City	1199	1175	Grady	-10,881	N/A
Chesapeake Oper.	Charlie #1-16	3N	5W	16	SE-SW-NE-SW	Carter-Knox	1217	1189	Grady	-10,173	N/A
Mack Oil Co.	Darnell #1	3N	5W	16	60' S 200' E of NW-NW	Knox	1236	1223	Grady	-10,379	N/A
Mack Oil Co.	Wheeler #1	3N	5W	16	NW	Carter-Knox	1203	1185	Grady	-10,507	N/A
Chevron USA	K. Richard #2	3N	5W	17	SW-NW-SW-NW	Carter-Knox	1279	1262	Grady	-8,231	-12,841
British American Oil	McKinney-Woods #1	3N	5W	17	SW-SW-SW-SW	Carter-Knox	1237	1218	Grady	-7,634	-12,464
Mack Oil Co.	Archer	3N	5W	17		Knox		1243	Grady		
Marathon Oil Co.	Willits #1	3N	5W	17	NE-NE-SE	Cox City	1251	1229	Grady	-9,529	N/A
Mack Oil Co.	Harris #1	3N	5W	17	1436' FSL 2505' FWL of NE	Carter-Knox	1250	1232	Grady	-10,085	N/A
Chevron USA	H. Marino #1	3N	5W	18	980' FSL 340' FWL	Carter-Knox	1277	1250	Grady	-7,923	-12,473
British American Oil	B. A. Teeter #1	3N	5W	18	C-SW-NE	Knox	1269	1258	Grady	-8,230	-12,395
Chevron USA	K. Richard #1	3N	5W	18	931' FSL 73' FEL	Carter-Knox	1256	1225	Grady		
Chesapeake Oper.	Mahaffey #1-19	3N	5W	19	S/2-S/2-N/2	Carter-Knox	1159	1138	Grady	-9,816	-13,346
British American Oil	Nellie English #1	3N	5W	19	SE-SE-NW	Carter-Knox	1161		Grady	-10,059	-13,509
Chevron USA	K. Sierra #1	3N	5W	20	SW-SW-SW-NW	Carter-Knox	1220	1219	Grady	-7,910	-12,530
British American Oil	Reed #1	3N	5W	20	NE	Knox	1207	1185	Grady		-12,463
Chevron USA	K. Sierra #2	3N	5W	20	SW-SE-SE-SW	Carter-Knox	1147	1120	Grady		-12,223
Pan American Petr.	Harrison #1	3N	5W	30	C-NE-SW-NE	Carter-Knox	1146	1129	Grady	-10,544	-13,824
British American	Sizemore Phipps	3N	6W	1			1286	1284	Grady	-9,604	-13,094
Chesapeake Oper.	Lyndell 1-1	3N	6W	1	SW-NE-NE	Carter-Knox	1303	1282	Grady	-7,257	-13,227
Apache Corp.	Bernard 1-4	3N	6W	4	C-SW-NE	Roaring Creek	1302	1280	Grady	-13,328	N/A
Chesapeake Oper.	D.D. Ward 1-12	3N	6W	12	NE-SW-SW-NE	Carter-Knox	1310	1286	Grady	-9,925	-13,260
Amoco Prod. Co.	Russell Unit 1	3N	6W	13		E. Knox	1263	1215	Grady	-10,997	-14,717

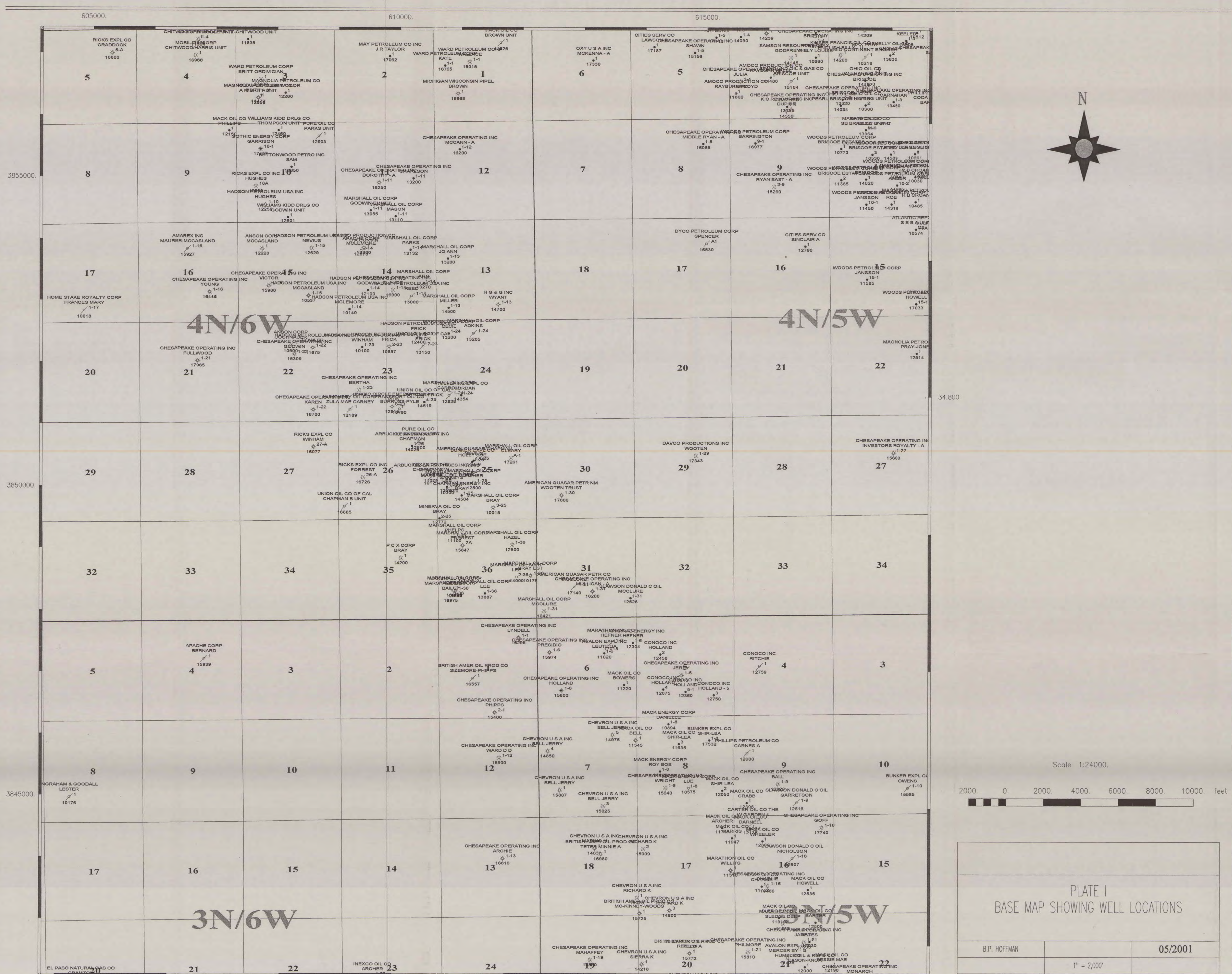
Operator	Well	Township	Range	Section	Location	Field	KB	GL	County	Top Hutson	Top Hunt.
Chesapeake Oper.	Archie 1-13	3N	6W	13	N/2-S/2-SW-NE	Cox City	1256	1226	Grady	-10,934	-14,564
Inexco Oil Co.	Archer 1-23	3N	6W	23	SW-NW-NE-SW	Wildcat	1228	1201	Grady	-14,692	N/A
Inexco Oil Co.	Mahaffey 1-25	3N	6W	25	C-NW	Wildcat	1181	1154	Grady	-13,619	N/A
Cities Service Co.	Lawson "E" 1(Scout)	4N	5W	5	C-NW	Golden Trend	1209	1208	Grady	-9,941	-13,033
Cities Service Co.	McKenna	4N	5W	6	C-SW-SE	W. Bradley	1180	1152	Grady	-9,710	-13,245
Cities Service Co.	Barrington A-1	4N	5W	8	C-NE	South Alex	1153	1126	Grady	-9,937	-13,017
Cities Service Co.	Sims A-1	4N	5W	9	C-SE-NE-SW	Wildcat	1144	1112	Grady	-9,696	-12,906
Woods Petro.	Jansson 1-15	4N	5W	15	NE-NW	Golden Trend	1118	1089	Grady	-9,282	N/A
Cities Service Co.	Sinclair A-1	4N	5W	16	N/2-N/2-S/2-NE	Golden Trend	1066	1065	Grady	-9,942	N/A
Cities Service Co.	Spencer A-1	4N	5W	17	C-NE	S. Bradly	1136	1103	Grady	-10,404	N/A
Max Pray &Redlands	Jones 1	4N	5W	22	C-SE-NE	Wildcat	1136	1122	Grady	-10,334	N/A
John L. Paxton	Quinlan 1	4N	5W	26	C-SW-SW	Wildcat	1144	1143	Grady	-10,508	N/A
Shell Oil Co.	Investors Royalty 1	4N	5W	27	C-SW-NE	Wildcat	1201	1179	Grady	-10,369	-13,620
Bunker Exploration	Beth Marie 1-28	4N	5W	29	SW-NE	Cox City	1139	1117	Grady	-10,721	-14,011
American Quasar	Wooten Trust 1-30	4N	5W	30	C-SW	E. Knox	1225	1196	Grady	-10,930	N/A
Arkla Exploration	McClure 1-31	4N	5W	31	S/2-SW-NW-SE	Knox	1270	1244	Grady	-10,520	N/A
Bunker Exploration	McClure 1-31 ST	4N	5W	31	C-NE-SW	Knox	1255	1236	Grady	-10,505	-14,015
Marshall Oil Co.	McClure 1-31	4N	5W	31	NE-SW-SW-SW	N. Cox City	1279	1255	Grady	-4,831	N/A
Phillips Petr. Co.	Hutson 3	4N	5W	31	SW-SW	Carter-Knox	1278	1277	Grady	N/A	N/A
Bunker Exploration	Betsy Ruth 1-32	4N	5W	32	C-SW	S. Alex	1213	1188	Grady	N/A	N/A
Michigan -Wisconson	Brown 1	4N	6W	1	C-SW/4	W. Bradley	1179	1155	Grady	-10,536	-13,646
May Petroleum	J. R. Taylor 1	4N	6W	2	C-NW-SW-NE	Chitwood	1118	1101	Grady	-10,772	-13,992
Anderson Prichard	Holder Unit 1	4N	6W	2	NW-SW	S.E. Bradley	1133	1113	Grady	-10,672	N/A
Mobil Oil Corp.	Mobil Britt 1	4N	6W	3	NW-NE-SW	Chitwood	1149	1123	Grady	-9,701	-14,171
Magnolia Petr. Co.	Britt Chitwood 1	4N	6W	3	C-NW-NW	Chitwood	1167	1147	Grady	-9,873	N/A
Magnolia Petr. Co.	Chitwood Cunn. 2	4N	6W	3	SE-NW-SW	N/A	1149	1129	Grady	-9,781	N/A
Magnolia Petr. Co.	J. R. Taylor 1	4N	6W	3	NW-SE	Chitwood	1175	1155	Grady	-10,027	N/A
Mobil Oil Corp.	Chitwood Harris 1	4N	6W	4		Chitwood	1155	1133	Grady	-10,035	-13,995
Magnolia Petr. Co.	Chitwood 1	4N	6W	4	C-NW-NE	Chitwood	1183	1163	Grady	-9,897	N/A
Gulf Oil Corp.	Ida 1	4N	6W	4	NW-NE-NW	Chitwood	1110	1099	Grady	-10,151	N/A
Ricks Exploration	Craddock	4N	6W	4		N/A	1189	1169	Grady	-11,016	-14,356
Bunker Exploration	Fowler 1	4N	6W	9		N/A	1202	1188	Grady	-10,328	-14,318
Mack Oil Co.	Phillips 1	4N	6W	9	NE-NE-NE	Chitwood	1201	1184	Grady	-9,961	N/A
Kidd Williams & Pure Oil	Godwin 1	4N	6W	10	SE-SW-SE	Chitwood	1125	1111	Grady	-9,291	N/A
Kidd Williams & Pure Oil	Snoda Sam-Thomas 1	4N	6W	10	NE-NE-NW	Chitwood	1151	1130	Grady	-9,841	N/A
Ricks Exploration	Hughes 1	4N	6W	10		S. Chitwood	1207	1190	Grady	-9,853	N/A
Buttonwood Petr.	Sam 1	4N	6W	10	SW-SW-NE	Chitwood	1164	1143	Grady	-9,996	N/A
Kidd Williams	Thompson 1	4N	6W	10	NE-NE-NW	Chitwood	1172	1152	Grady	-9,843	N/A
Bunker Exploration	Garrison 1-10	4N	6W	10	C-NW	Chitwood	1211	1192	Grady	-9,789	-14,249
Hadson Petroleum USA	Hughes 1-10	4N	6W	10	NW-SE-SW	Chitwood	1203	1187	Grady	-9,777	N/A
Chesapeake Oper.	Charlson #1-11	4N	6W	11	NW-NE-SE				Grady	-10,973	N/A
Chesapeake Oper.	Dorothy A#1-11	4N	6W	11	NE-NE-SW		1168	1148	Grady		-14,236
Marshall Oil Co.	Mason 1-11	4N	6W	11	SE-SW-SW-SE	E. Rush Springs	1146	1120	Grady	-10,979	N/A
Humble Oil Co.	Godwin 1	4N	6W	11	NE-NE-SW	Wildcat	1166	1147	Grady	-10,924	-14,217
Marshall Oil Co.	Emmet Godwin 1	4N	6W	11		E. Rush Springs	1173	1157	Grady	-10,887	N/A

Operator	Well	Township	Range	Section	Location	Field	KB	GL	County	Top Hutson	Top Hunt.
Chesapeake Oper.	McCann A#1-12	4N	6W	12	NW-SE-NW				Grady		-13,943
American Natural Gas	Brown A-1	4N	6W	12	C-NW	W. Bradley	1150	1127	Grady	-10,658	-13,940
Marshall Oil Co.	Jo Ann 1-13	4N	6W	13	SW-NW	Chitwood	1225	1203	Grady	-10,965	N/A
Marshall Oil Co.	Miller 1-13	4N	6W	13	C-SW-SW	E. Rush Springs	1238	1212	Grady	-10,977	N/A
H. G.&G. Inc.	Wyant 1-13	4N	6W	13	N/2-SW-SE	N/A	1212	1191	Grady	-10,959	N/A
Hadson Petroleum	McLemore 1-14	4N	6W	14	SW/4-SW/4	Chitwood	1200	1181	Grady	-7,820	N/A
Amoco Prod. Co.	B. A. Curvin 1-14	4N	6W	14	W/2-E/2-NW	Chitwood	1200	1168	Grady	-10,830	N/A
Marshall Oil Co.	Parks 1-14	4N	6W	14	C-NE	Chitwood	1205	1182	Grady	-10,945	N/A
Marshall Oil Co.	Ann 1-14	4N	6W	14	NE-SE	Cox City	1210	1190	Grady	-10,990	N/A
Bunker Exploration	Reed 1-14	4N	6W	14	C-SE	S. Chitwood	1223	1206	Grady	-10,927	N/A
Chesapeake Oper.	Claude 1-14	4N	6W	14	C-SW-NW-SE	Carter-Knox	1229	1197	Grady	-10,711	-14,391
Hadson Ohio Oil	Godwin 1-14	4N	6W	14	SW-NE-SW	Chitwood	1168	1151	Grady		
Anson Corp.	McCasland 1	4N	6W	15	C-NW	Chitwood	1167	1152	Grady	-9,783	N/A
Hadson Petroleum	McCasland 1-15	4N	6W	15	SE-SE-NW-SE	Chitwood	1172	1156	Grady	-9,053	N/A
Hadson Petroleum	Nevius 1-15	4N	6W	15	C-NE	Wildcat	1153	1136	Grady	-8,837	N/A
Chesapeake Oper.	Victor 1	4N	6W	15	W/2-NE-SW	Carter-Knox	1172	1145	Grady	-9,558	-13,958
Amarex Inc.	Mauer-McCasland	4N	6W	16	16-4N-6W-	S. Chitwood	1224	1200	Grady	-10,760	N/A
Chesapeake Oper.	Young 1	4N	6W	16	E/2-SE-NW-SE	S. Alex	1198	1170	Grady	-10,652	-14,032
Chesapeake Oper.	Fullwood	4N	6W	21	E/2-W/2-SW-NE	Carter-Knox	1260	1238	Grady	-10,625	-13,940
Chesapeake Oper.	Karen #1-22	4N	6W	22	C-S/2-SE		1253	1233	Grady		-13,862
Hadson Petroleum	Fowler 1	4N	6W	22	C-NE	Chitwood	1213	1197	Grady	-9,076	N/A
Amoco Prod. Co.	Jordan 1	4N	6W	22	W/2-E/2-SW	Chitwood	1218	1190	Grady	-9,842	-13,294
Chesapeake Oper.	Godwin 1	4N	6W	22	C-NW-SW-NE	Carter-Knox	1180	1158	Grady	-9,370	-13,310
Union Oil Co.	Bertha Frick 4	4N	6W	23		Chitwood	1263	1235	Grady		N/A
Humphrey Oil Corp.	Carney	4N	6W	23	SW-SW	Wildcat	1259	1245	Grady	-9,048	N/A
Chesapeake Oper.	Bertha Frick 1	4N	6W	23	SE-NW-SW	Carter-Knox	1240	1217	Grady		
Humphrey Oil Corp.	Burruss-Pyle	4N	6W	23	C-SW-SE	S. Chitwood	1237	1221	Grady	-8,075	N/A
Union Oil Co.	Frick 6	4N	6W	23	SW-NW-SW-SE	Chitwood	1253	1230	Grady	-8,132	N/A
Hadson Petroleum	Frick 5	4N	6W	23	C-NE-NE	S. Alex	1238	1216	Grady	-10,672	N/A
Hadson Petroleum	Winham 1	4N	6W	23	C-NW	Chitwood	1197	1179	Grady	-7,823	N/A
Hadson Petroleum	Frick 2	4N	6W	23	W/2-W/2-NE	Chitwood	1207	1190	Grady	-9,133	N/A
Union Oil Co.	Frick 7	4N	6W	23	NE	Chitwood	1241	1224	Grady	-10,614	N/A
Bunker Exploration	Bertha Frick 3	4N	6W	23	C-SE	Knox	1277	1243	Grady	-7,093	N/A
Bunker Exploration	J.J. Jordan	4N	6W	24	C-SW	Wildcat	1226	1206	Grady	-10,724	N/A
Marshall Oil Co.	Cecil	4N	6W	24	NW	Chitwood	1228	1206	Grady	-10,972	N/A
Marshall Oil Co.	Adkins	4N	6W	24	NE-NW	Chitwood	1233	1210	Grady	-10,967	N/A
Marshall Oil Co.	Carroll	4N	6W	24	W/2-SW	E. Pleasant View	1224	1201	Grady	-10,586	N/A
Rivondale Oil	Holly Sue 2	4N	6W	25	NW-NW-NW	Knox	1231	1209	Grady	-6,974	N/A
Marshall Oil Co.	Bray 3	4N	6W	25	C-W/2-SW-SE	S. Alex	1262	1245	Grady	-5,588	N/A
Bunker Exploration	Nevius 1A	4N	6W	25	N/2-S/2-NW	Wildcat	1253	1229	Grady	-10,357	N/A
Marshall Oil Co.	Sarkey	4N	6W	25	SE-NW-SW	S. Alex	1248	1233	Grady	-7,372	N/A
Marshall Oil Co.	Lee	4N	6W	25	NE-SW-NW-SW	E. Pleasant View	1257	1234	Grady	N/A	N/A
Minerva Oil Co.	Bray 2	4N	6W	25		S. Alex	1271	1249	Grady		
Chapman Energy	Bray 1	4N	6W	25	C-SW	Knox	1242	1212	Grady	-7,078	N/A
Marshall Oil Co.	Fisher	4N	6W	25	NE-SW	S. Alex	1236	1218	Grady	-6,134	N/A

Operator	Well	Township	Range	Section	Location	Field	KB	GL	County	Top Hutson	Top Hunt.
Bunker Exploration	Holly Sue 1-25	4N	6W	25	408' FSL 1892 FWL of NW	Chitwood	1252	1230	Grady	-6,388	N/A
Marshall Oil Co.	Cleary #1-A	4N	6W	25	C-S/2-NE	S. Alex	1213	1189	Grady	-10,792	-14,167
Arbuckle Enterprises	Chapman #1-26	4N	6W	26	C-NE	S. Alex	1256	1234	Grady	-8,122	N/A
Pure Oil Co.	Chapman B #1	4N	6W	26	NW-SW-SW	Wildcat	1312	1292	Grady		-13,338
Ricks Exploration	Forest 26-A	4N	6W	26	330' S of C of W/2	Wildcat	1296	1269	Grady	-9,264	-13,064
Texas Co.	Chapman #1	4N	6W	26	NE-NE-SE	Wildcat	1224		Grady	-8,327	N/A
Ricks Exploration	Winham #27-A	4N	6W	27	C-NE	Wildcat	1259	1232	Grady	-9,551	-13,131
L.P.C.X. Corp.	Bray #1	4N	6W	35	C-NE	S. Pleasant View	1303	1281	Grady	-9,597	-12,937
Marshall Oil Co.	R. E. L. #36-1	4N	6W	36	SE-NW-SW	North Knox	1298	1271	Grady	-10,149	N/A
Marshall Oil Co.	Phelps #1-36A	4N	6W	36	SE-NW-NW	South Alex	1262	1238	Grady		
Marshall Oil Co.	Anderson	4N	6W	36			1299	1271	Grady	-8,806	N/A
Marshall Oil Co.	Forest #1-36	4N	6W	36	C-NW	S. Alex	1281	1259	Grady	-7,689	N/A
Bunker Exploration	Bailey #1-36	4N	6W	36	C-W/2-SW	Wildcat	1286	1260	Grady	-8,834	-13,464
Marshall Oil Co.	Hazel #1-36	4N	6W	36	NE	S. Alex	1205	1187	Grady	-5,344	
Marshall Oil Co.	Hazel #1-37	4N	6W	36	NE	S. Alex	1205	1187	Grady	-10,174	N/A
Marshall Oil Co.	Bray Estate #1-36	4N	6W	36	NE-NE-SE	S. Alex	1255	1231	Grady	-5,125	

PLATES

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, & 18.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Scale 1:24000.
2000. 0. 2000. 4000. 6000. 8000. 10000. feet
PLATE I
BASE MAP SHOWING WELL LOCATIONS
B.P. HOFFMAN
05/2001
1" = 2,000'

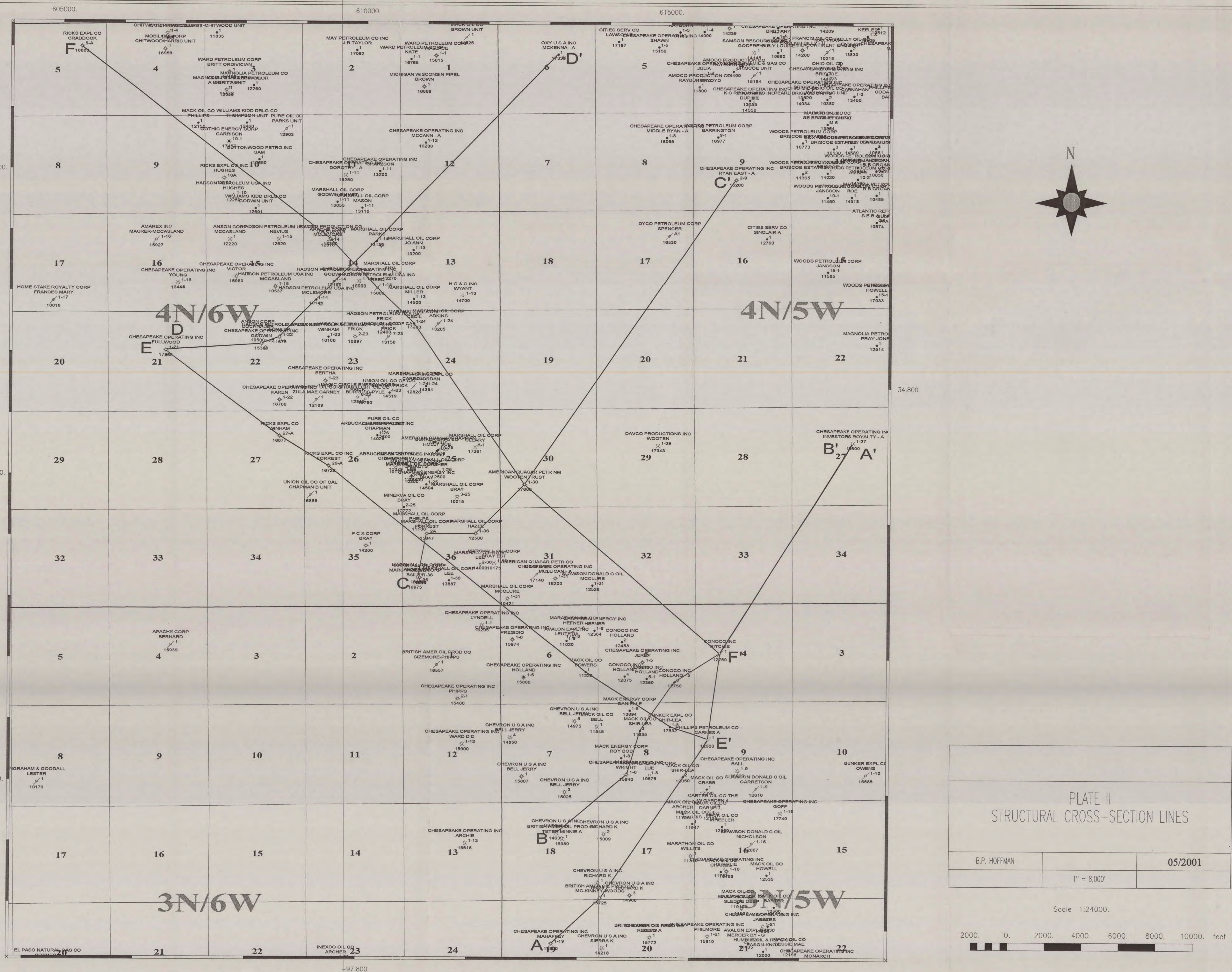
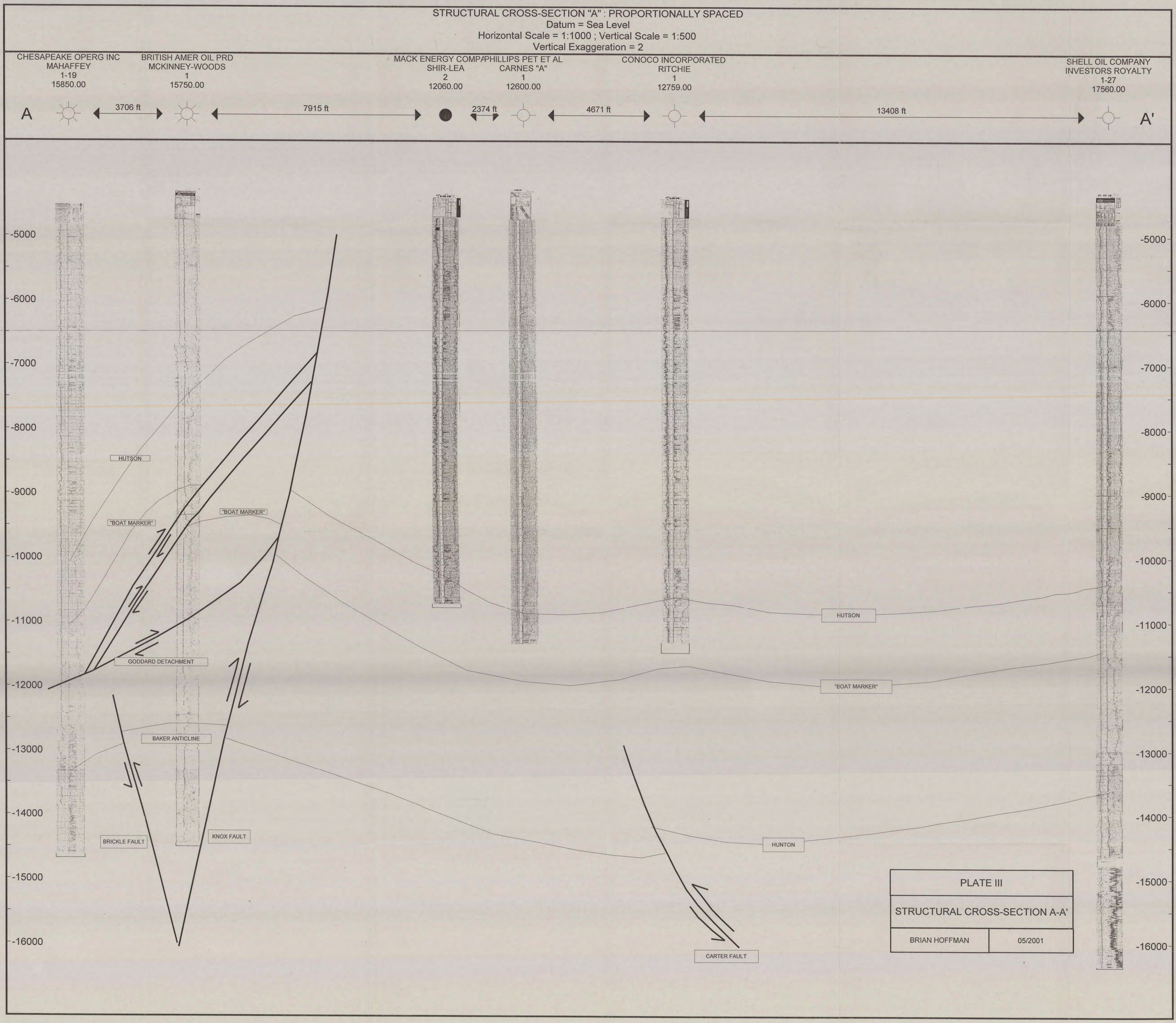


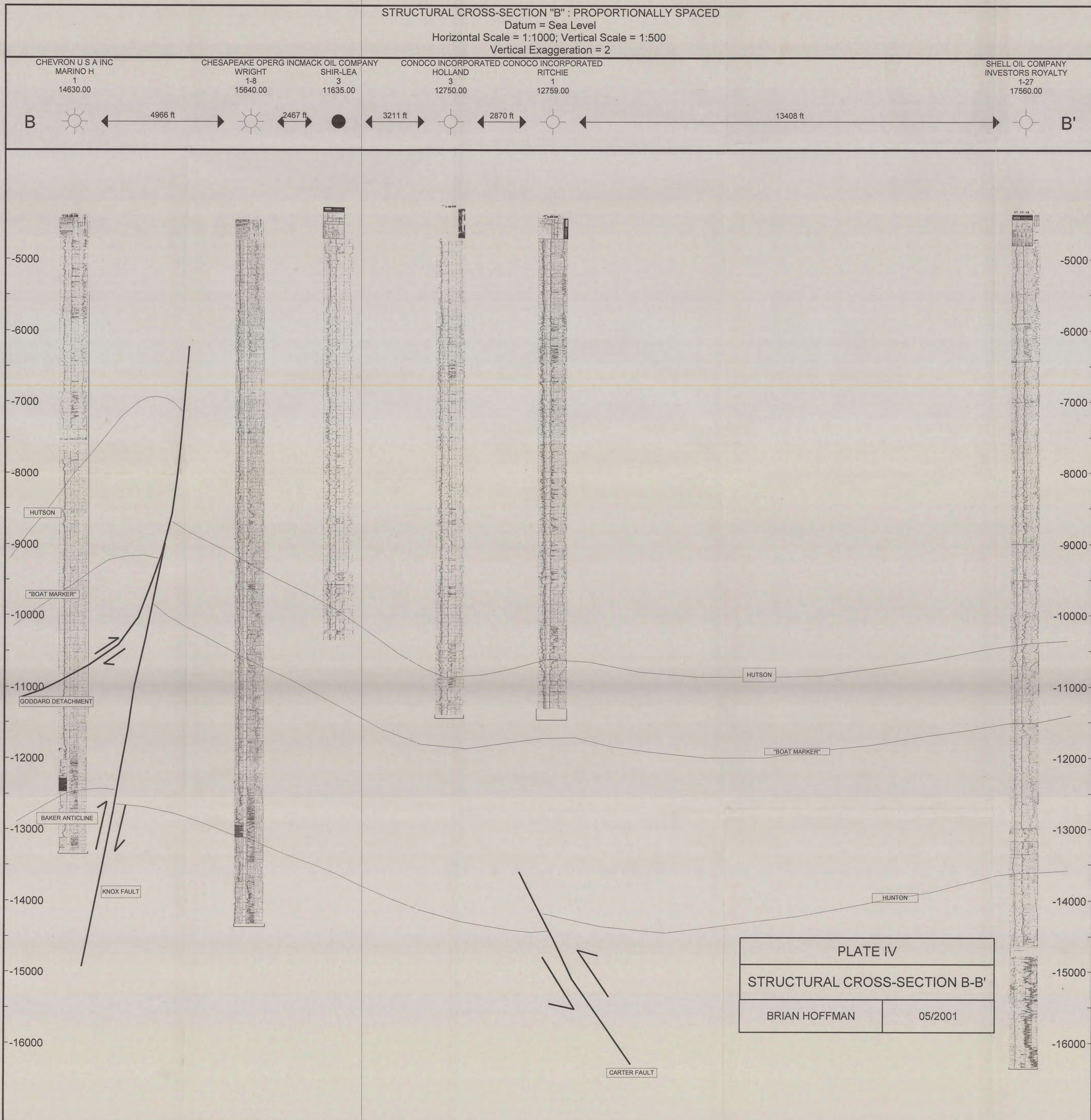
PLATE II
STRUCTURAL CROSS-SECTION LINES

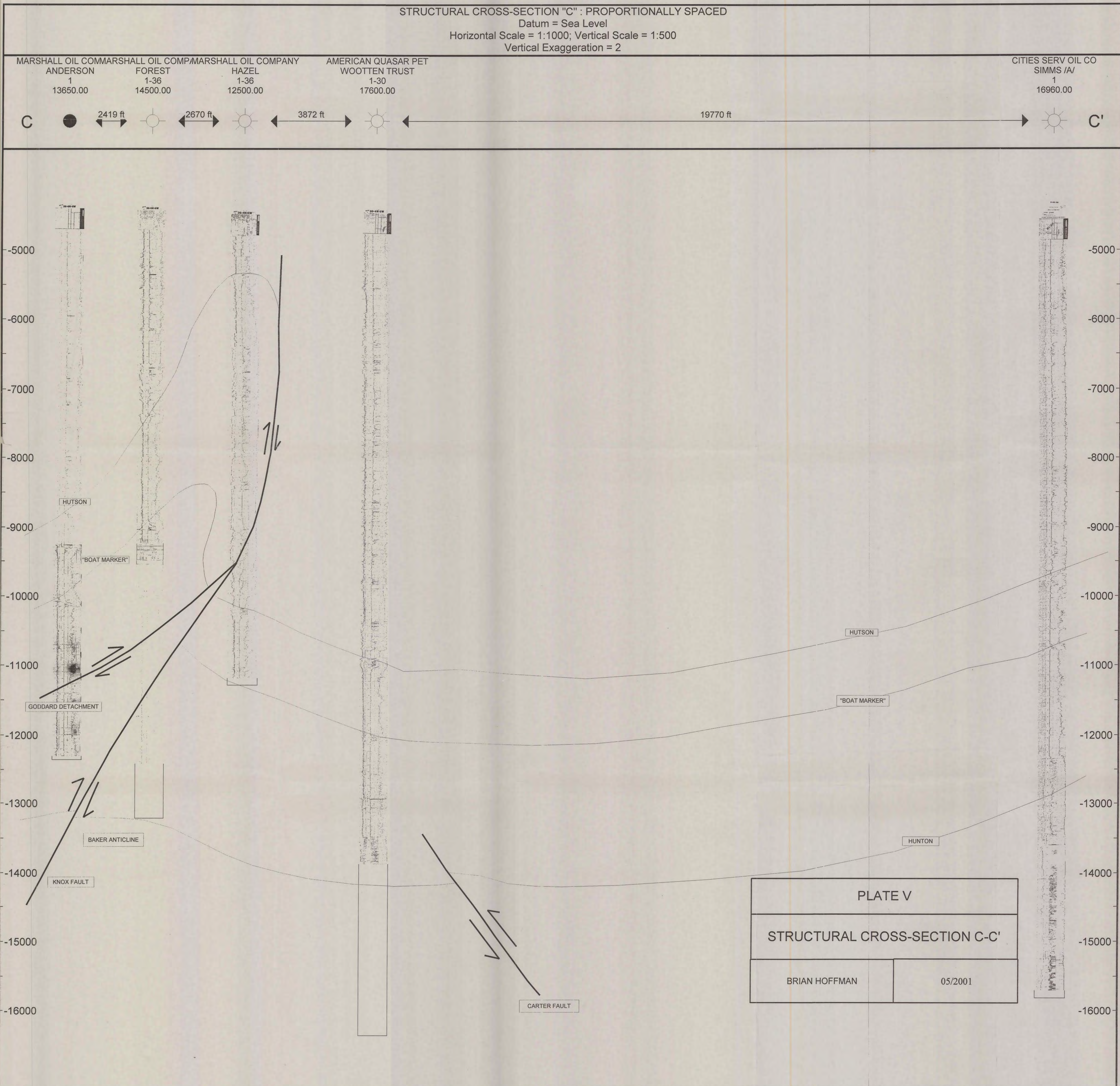
B.P. HOFFMAN		05/2001
	1" = 8,000'	

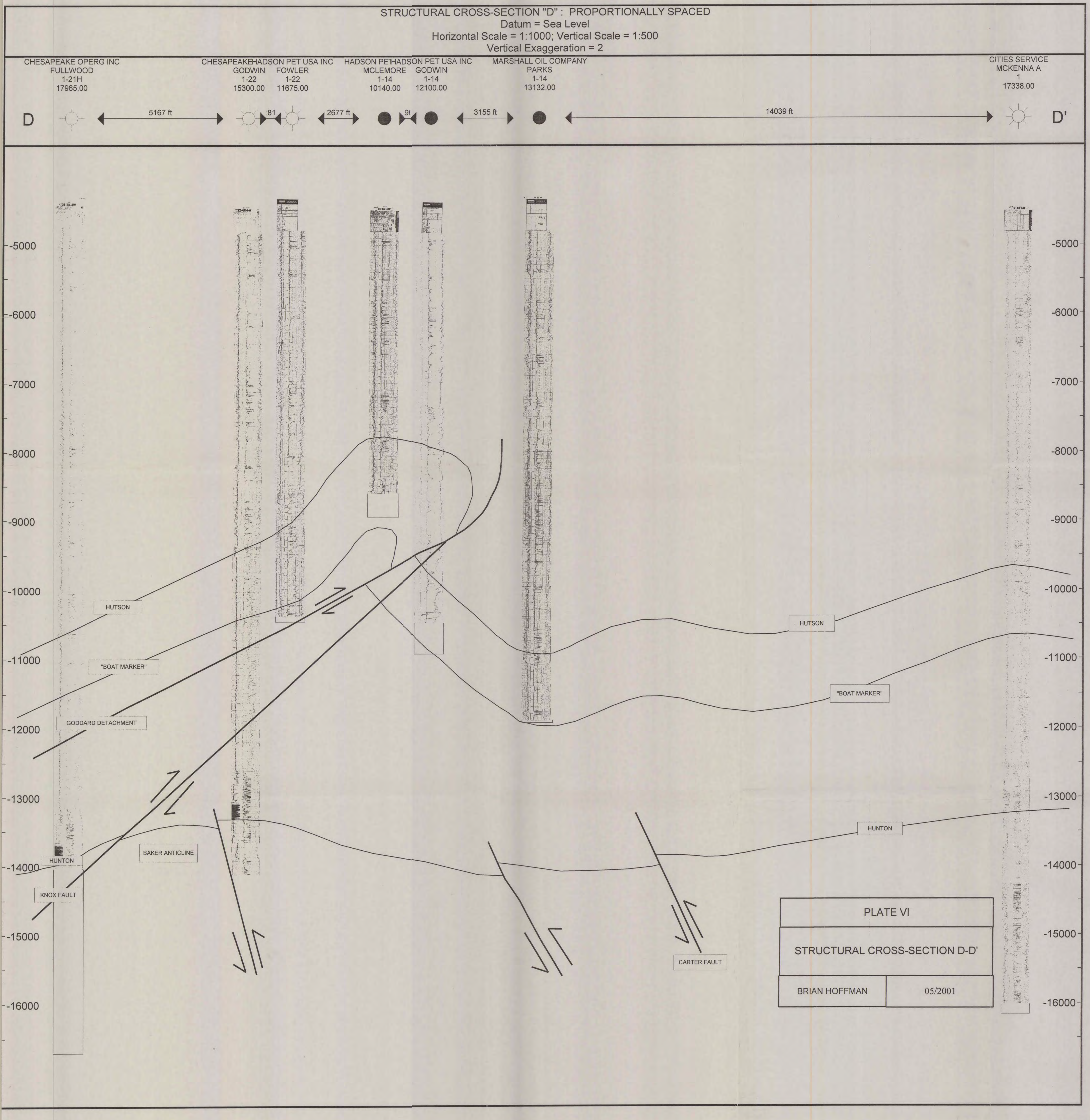
Scale 1:24000.

2000. 0. 2000. 4000. 6000. 8000. 10000. feet

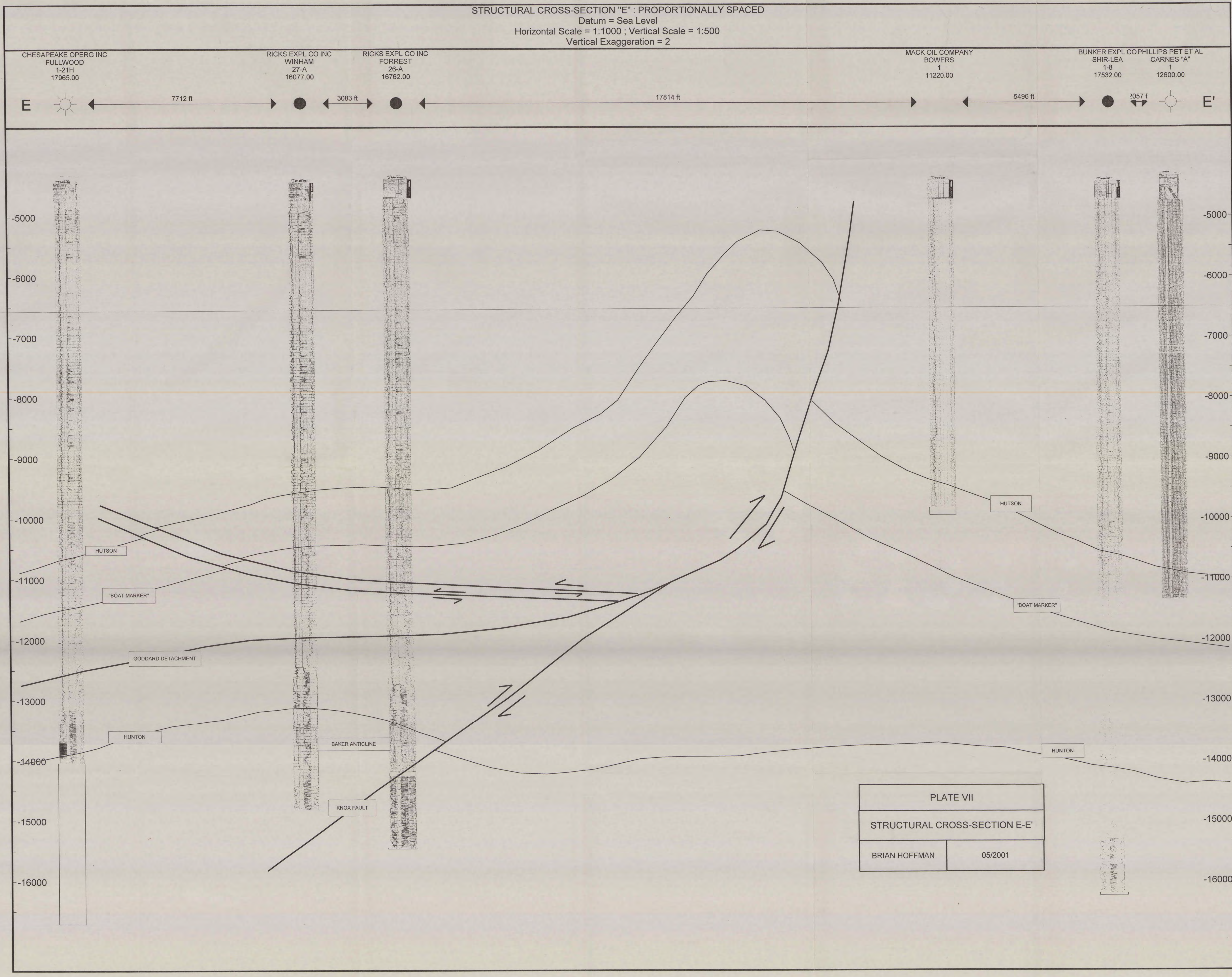

STRUCTURAL CROSS-SECTION "A" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1:1000 ; Vertical Scale = 1:500
Vertical Exaggeration = 2
CHESAPEAKE OPERG INC MAHAFFEY 1-19 15850.00
BRITISH AMER OIL PRD MCKINNEY-WOODS 1 15750.00
MACK ENERGY COMPA SHIR-LEA 2 12060.00
PHILLIPS PET ET AL CARNES "A" 1 12600.00
CONOCO INCORPORATED RITCHIE 1 12759.00
SHELL OIL COMPANY INVESTORS ROYALTY 1-27 17560.00
A
A'
3706 ft
7915 ft
2374 ft
4671 ft
13408 ft
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
BAKER ANTICLINE
BRICKLE FAULT
KNOX FAULT
HUNTON
CARTER FAULT
PLATE III
STRUCTURAL CROSS-SECTION A-A'
BRIAN HOFFMAN
05/2001


STRUCTURAL CROSS-SECTION "B" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1:1000; Vertical Scale = 1:500
Vertical Exaggeration = 2
CHEVRON U S A INC
MARINO H
1
14630.00
CHESAPEAKE OPERG INC
WRIGHT
1-8
15640.00
MACK OIL COMPANY
SHIR-LEA
3
11635.00
CONOCO INCORPORATED
HOLLAND
3
12750.00
CONOCO INCORPORATED
RITCHIE
1
12759.00
SHELL OIL COMPANY
INVESTORS ROYALTY
1-27
17560.00
B
4966 ft
2467 ft
3211 ft
2870 ft
13408 ft
B'
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
BAKER ANTICLINE
KNOX FAULT
HUTSON
"BOAT MARKER"
HUNTON
CARTER FAULT
PLATE IV
STRUCTURAL CROSS-SECTION B-B'
BRIAN HOFFMAN
05/2001


STRUCTURAL CROSS-SECTION "C" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1:1000; Vertical Scale = 1:500
Vertical Exaggeration = 2
MARSHALL OIL COMPANY ANDERSON 1 13650.00
MARSHALL OIL COMPANY FOREST 1-36 14500.00
MARSHALL OIL COMPANY HAZEL 1-36 12500.00
AMERICAN QUASAR PET WOOTTEN TRUST 1-30 17600.00
CITIES SERV OIL CO SIMMS /A/ 1 16960.00
C
2419 ft
2670 ft
3872 ft
19770 ft
C'
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
BAKER ANTICLINE
KNOX FAULT
HUNTON
CARTER FAULT
PLATE V
STRUCTURAL CROSS-SECTION C-C'
BRIAN HOFFMAN
05/2001

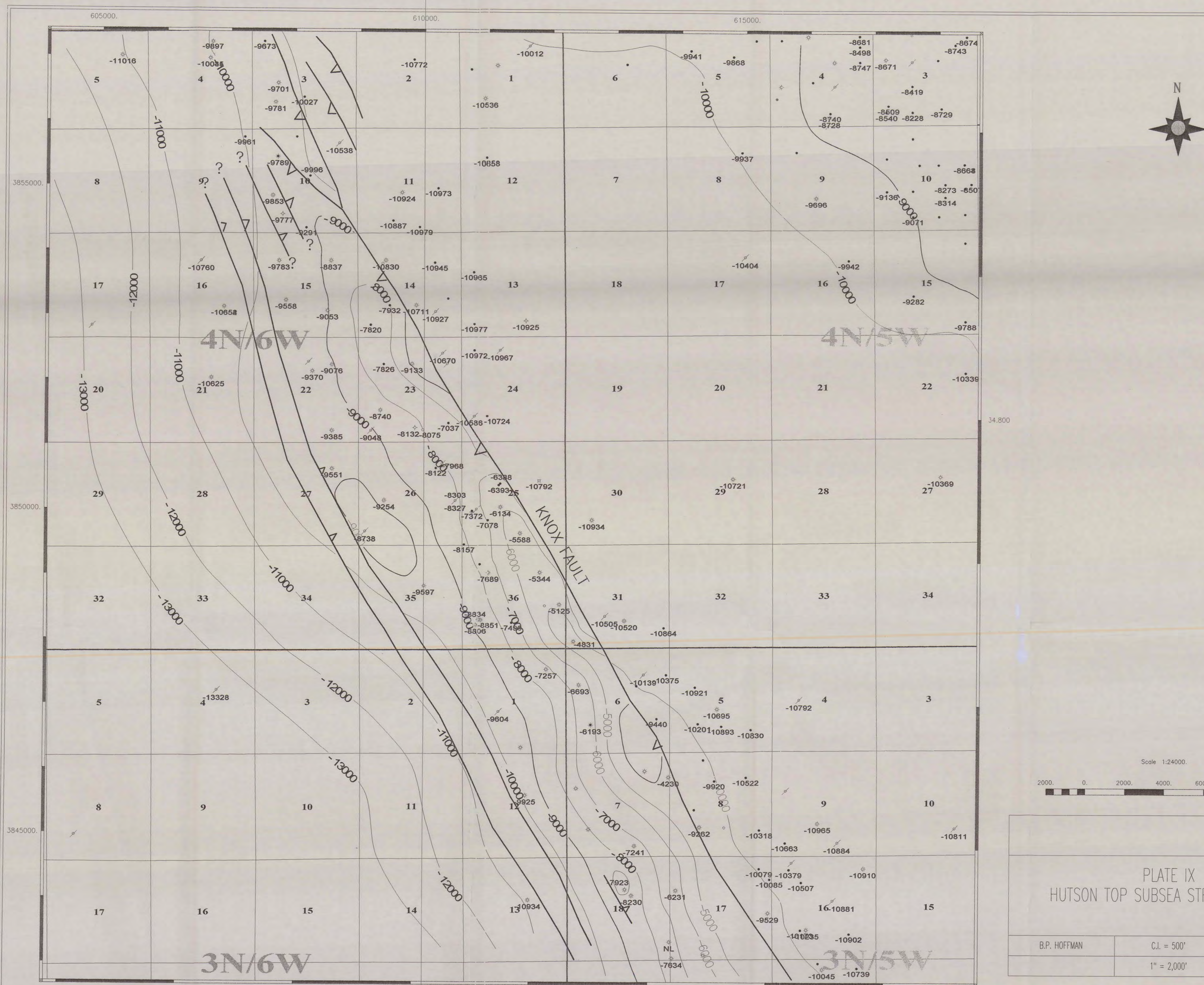


STRUCTURAL CROSS-SECTION "D" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1:1000; Vertical Scale = 1:500
Vertical Exaggeration = 2
CHESAPEAKE OPERG INC
FULLWOOD
1-21H
17965.00
CHESAPEAKEHADSON PET USA INC
GODWIN FOWLER
1-22 1-22
15300.00 11675.00
HADSON PETHADSON PET USA INC
MCLEMORE GODWIN
1-14 1-14
10140.00 12100.00
MARSHALL OIL COMPANY
PARKS
1-14
13132.00
CITIES SERVICE
MCKENNA A
1
17338.00
D
5167 ft
2677 ft
3155 ft
14039 ft
D'
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
HUNTON
KNOX FAULT
BAKER ANTICLINE
CARTER FAULT
PLATE VI
STRUCTURAL CROSS-SECTION D-D'
BRIAN HOFFMAN
05/2001



STRUCTURAL CROSS-SECTION "E" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1:1000 ; Vertical Scale = 1:500
Vertical Exaggeration = 2
CHESAPEAKE OPERG INC
FULLWOOD
1-21H
17965.00
RICKS EXPL CO INC
WINHAM
27-A
16077.00
RICKS EXPL CO INC
FORREST
26-A
16762.00
MACK OIL COMPANY
BOWERS
1
11220.00
BUNKER EXPL CO
SHIR-LEA
1-8
17532.00
PHILLIPS PET ET AL
CARNES "A"
1
12600.00
E
7712 ft
3083 ft
17814 ft
5496 ft
2057 f
E'
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
HUNTON
BAKER ANTICLINE
KNOX FAULT
HUTSON
"BOAT MARKER"
HUNTON
PLATE VII
STRUCTURAL CROSS-SECTION E-E'
BRIAN HOFFMAN
05/2001

STRUCTURAL CROSS-SECTION " F" : PROPORTIONALLY SPACED
Datum = Sea Level
Horizontal Scale = 1 in per 1000 ft; Vertical Scale = 1 in per 500 ft
Vertical Exaggeration = 2
RICKS EXPL CO INC
CRADDOCK
5-A
18800.00
AMOCO PROD CO
CURVIN B A
1-14
13300.00
HADSON PET USA INC
REED
1-14
12324.00
MARSHALL OIL COMPANY
CECIL
1-24
13200.00
AMERICAN QUASAR PET
WOOTTEN TRUST
1-30
17600.00
CONOCO INCORPORATED
RITCHIE
1
12759.00
F
16901 ft
3897 ft
2527 ft
10596 ft
13811 ft
F'
-5000
-6000
-7000
-8000
-9000
-10000
-11000
-12000
-13000
-14000
-15000
-16000
-17000
HUTSON
"BOAT MARKER"
GODDARD DETACHMENT
HUNTON
CARTER FAULT
PLATE VIII
STRUCTURAL CROSS-SECTION F-F'
BRIAN HOFFMAN
05/2001

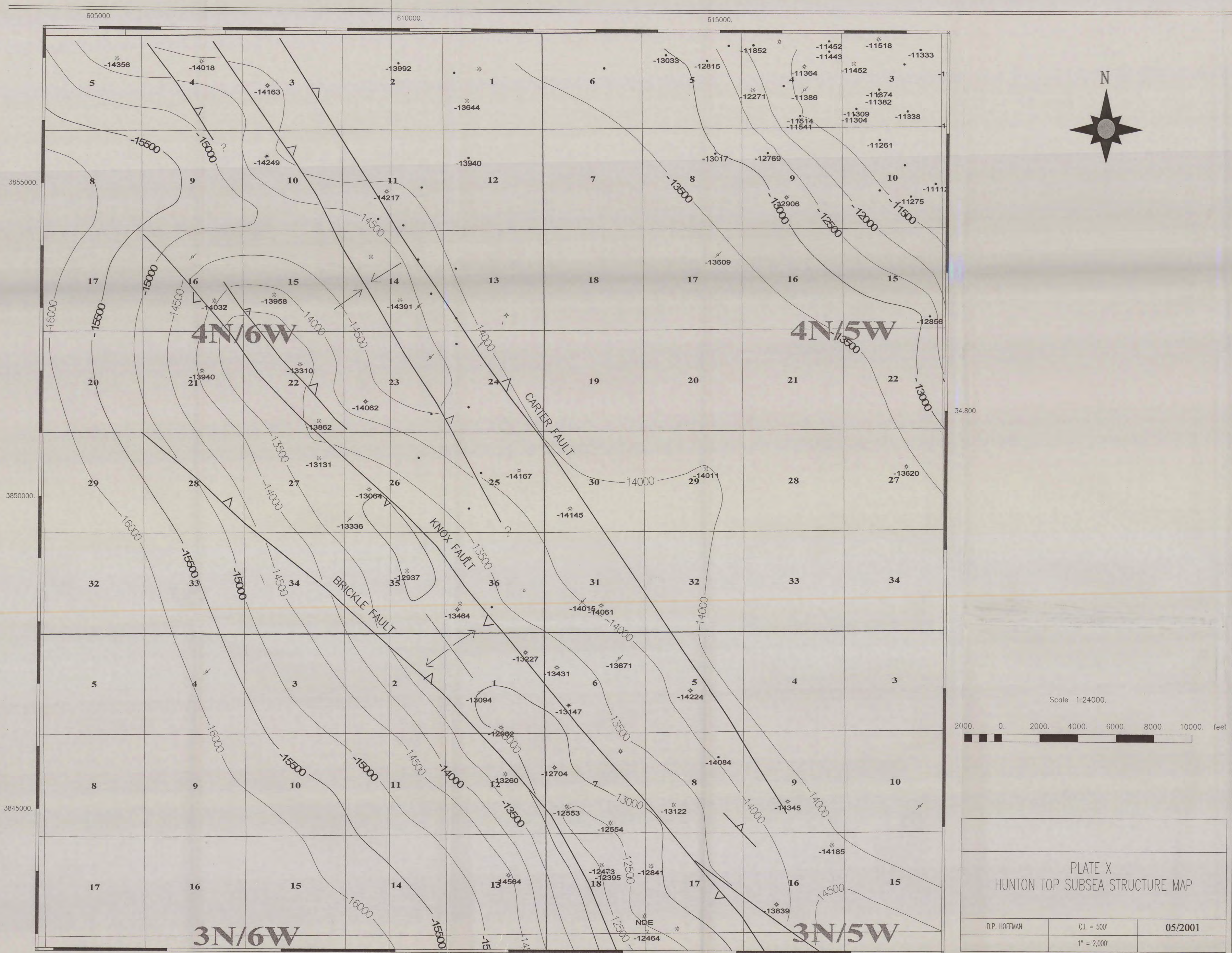


Scale 1:24000.

2000. 0. 2000. 4000. 6000. 8000. 10000. feet

PLATE IX
HUTSON TOP SUBSEA STRUCTURE MAP

B.P. HOFFMAN	C.I. = 500'	05/2001
	1" = 2,000'	


4N/6W
4N/5W
3N/6W
3N/5W
CARTER FAULT
KNOX FAULT
BRICKLE FAULT
N
Scale 1:24000.
2000. 0. 2000. 4000. 6000. 8000. 10000. feet
PLATE X
HUNTON TOP SUBSEA STRUCTURE MAP
B.P. HOFFMAN
C.I. = 500'
1" = 2,000'
05/2001

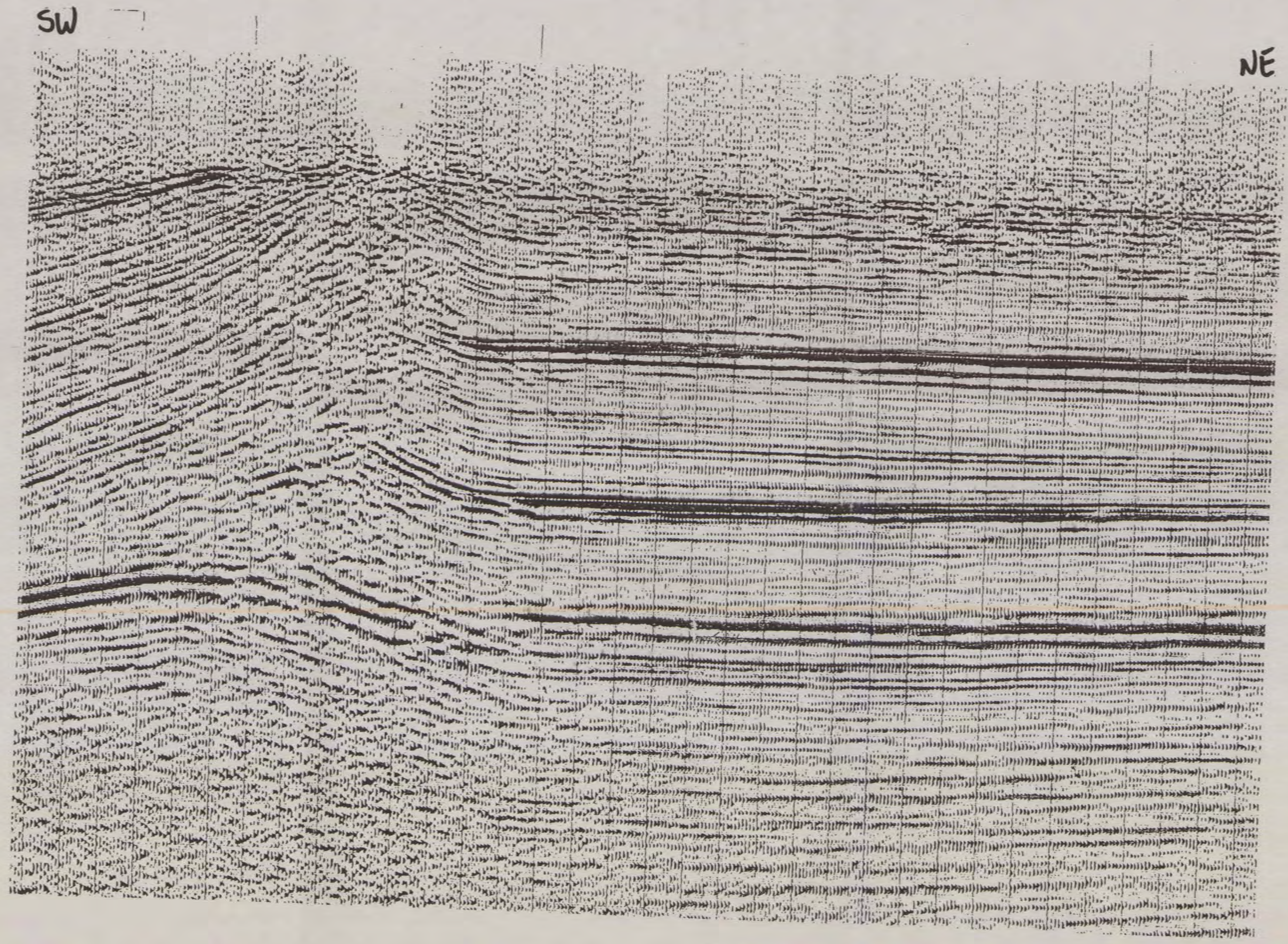


PLATE XI
UNINTERPRETED SOUTHERN SEISMIC LINE
BRIAN HOFFMAN 05/2001

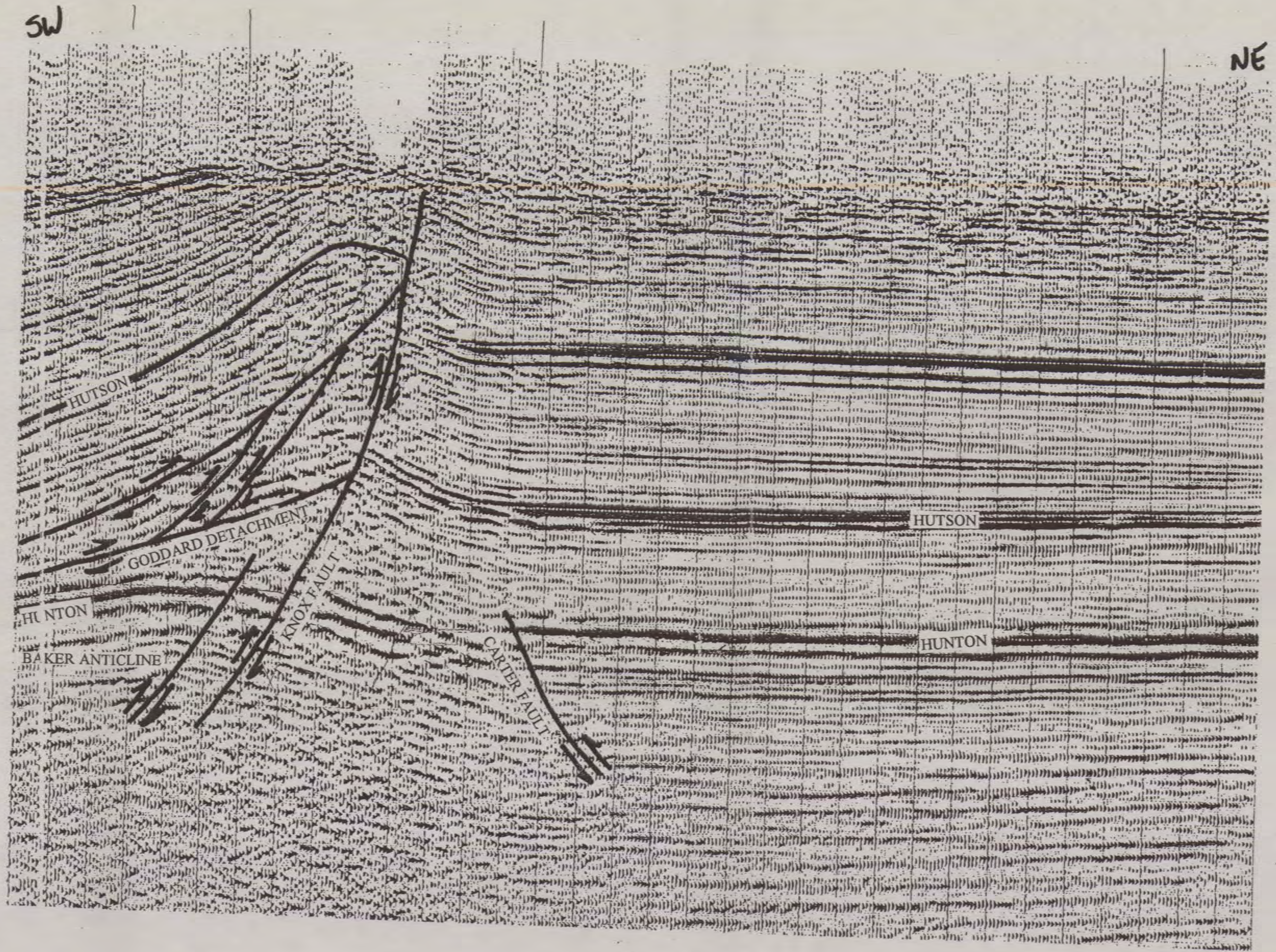


PLATE XII	
INTERPRETED SOUTHERN SEISMIC LINE	
BRIAN HOFFMAN	05/2001

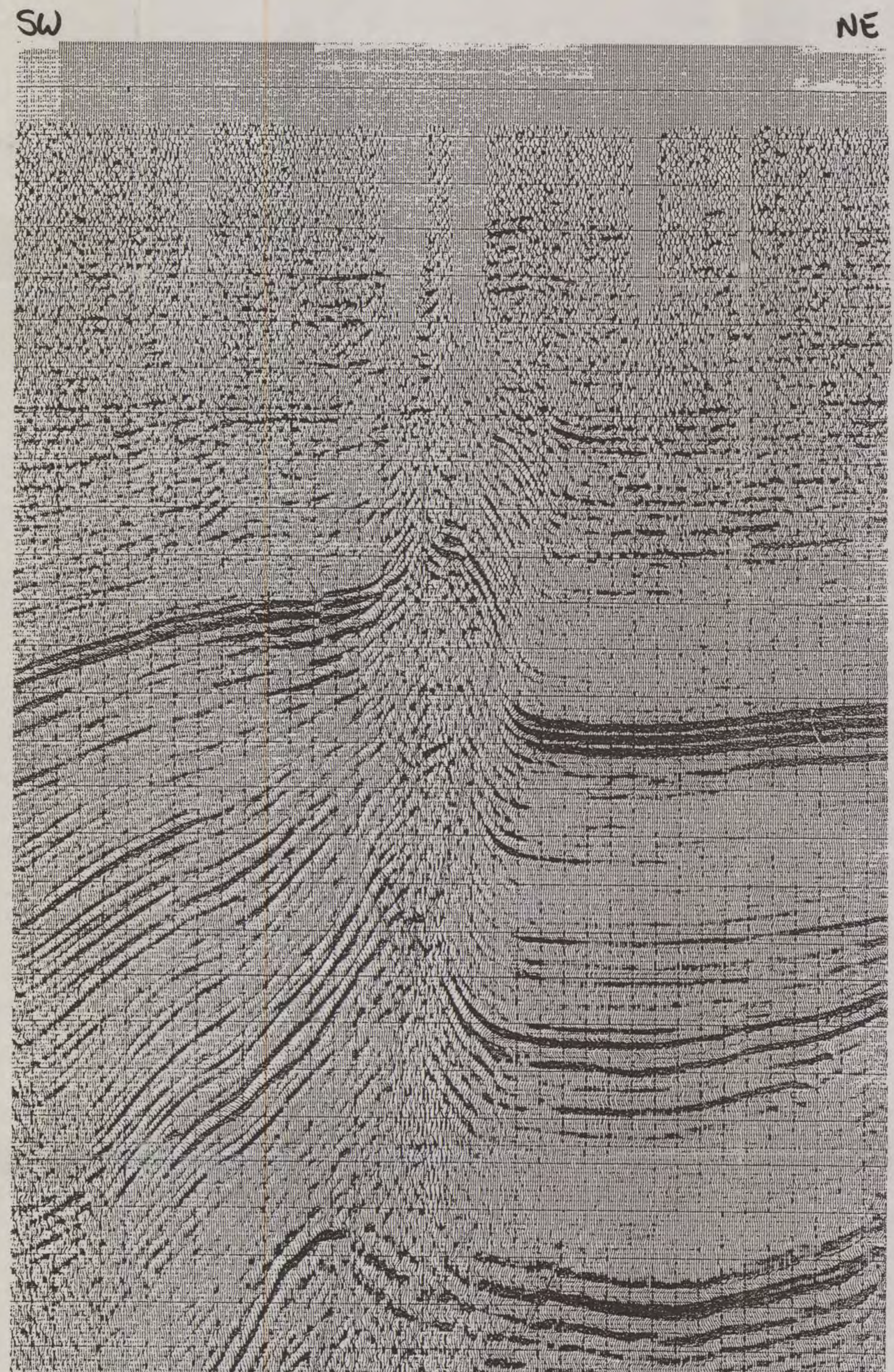


PLATE XIII
UNINTERPRETED MIDDLE SEISMIC LINE
BRIAN HOFFMAN 05/2001

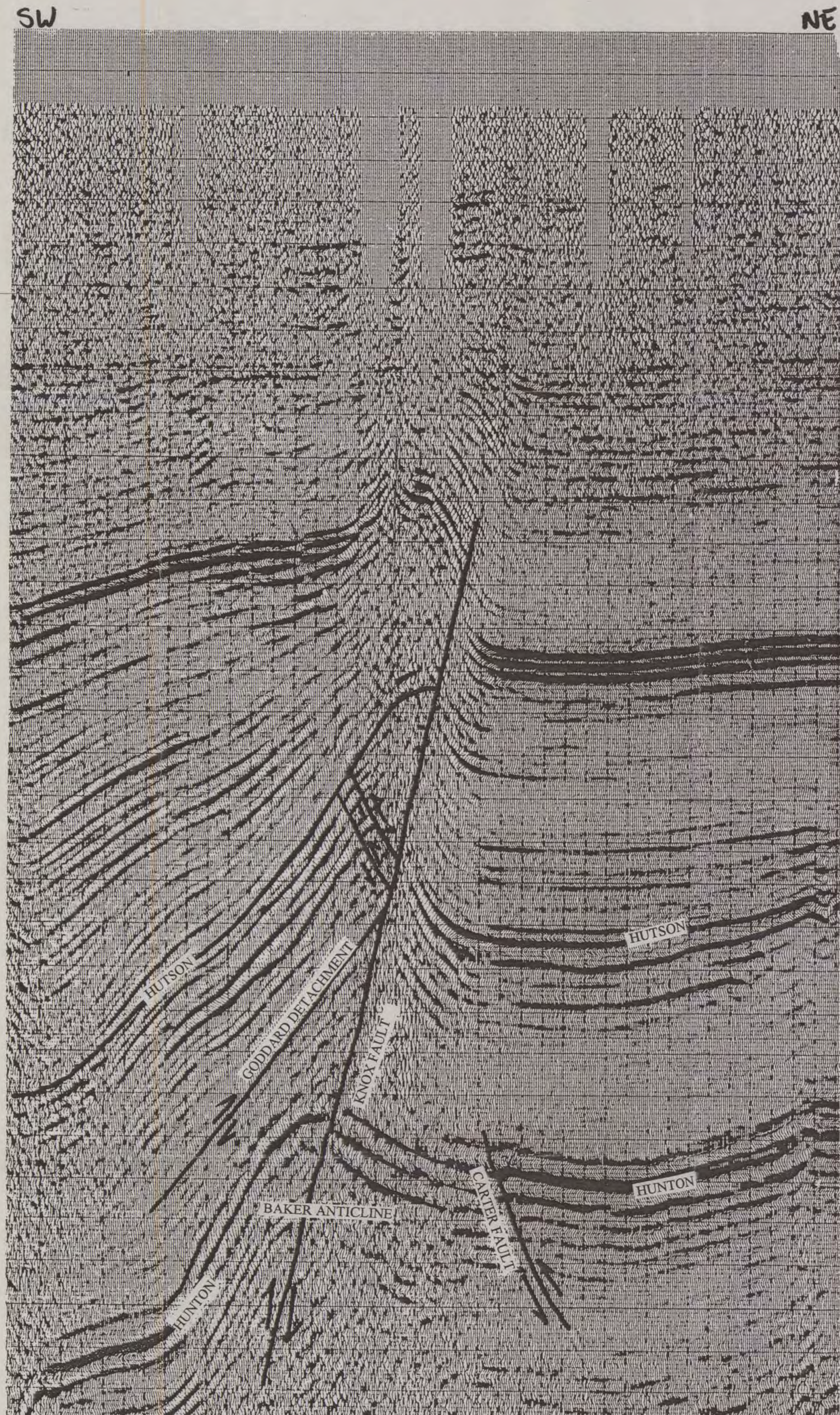


PLATE XIV

INTERPRETED MIDDLE SEISMIC LINE

BRIAN HOFFMAN 05/2001

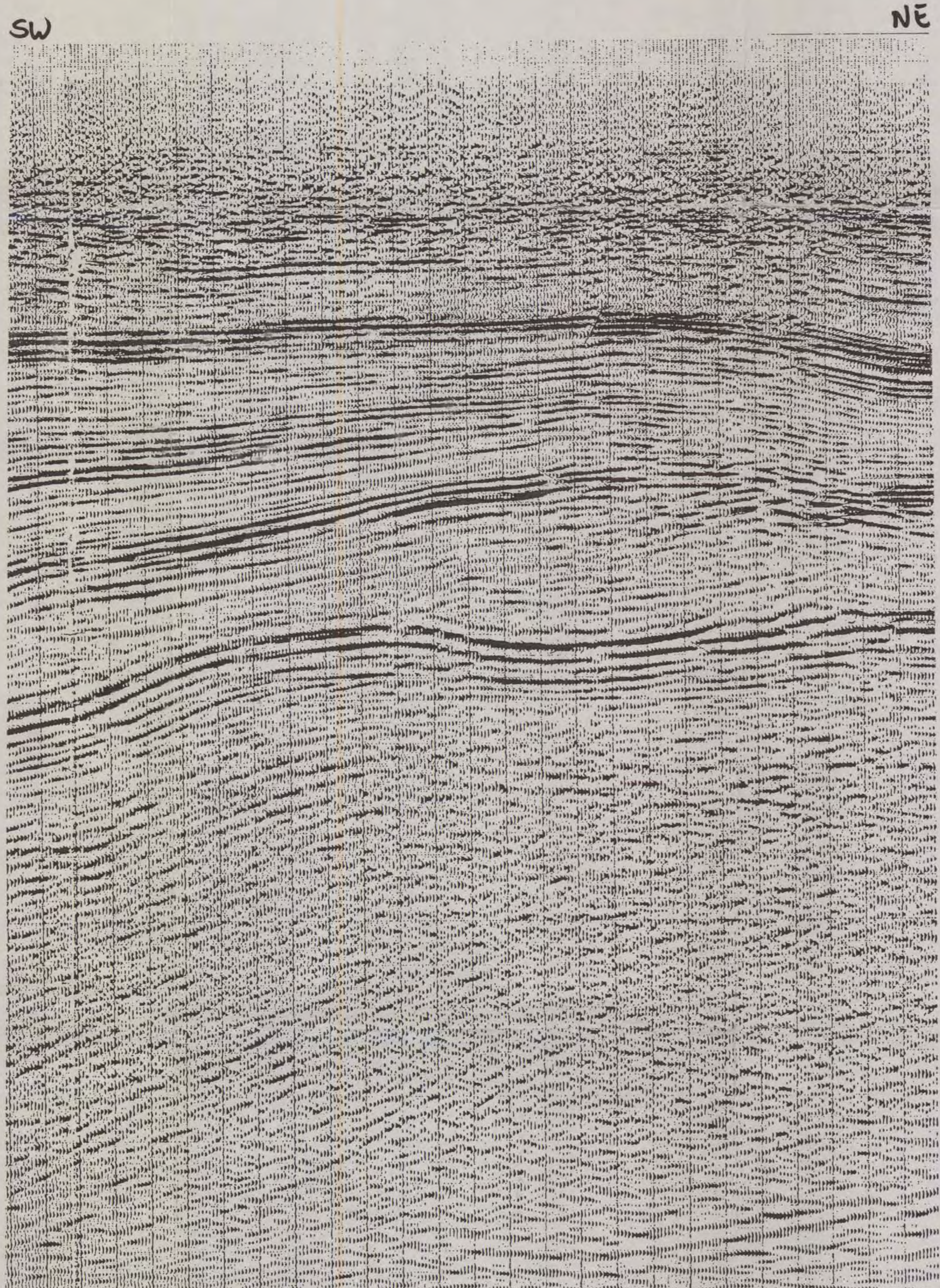


PLATE XV

UNINTERPRETED NORTHERN SEISMIC LINE

BRIAN HOFFMAN 05/2001

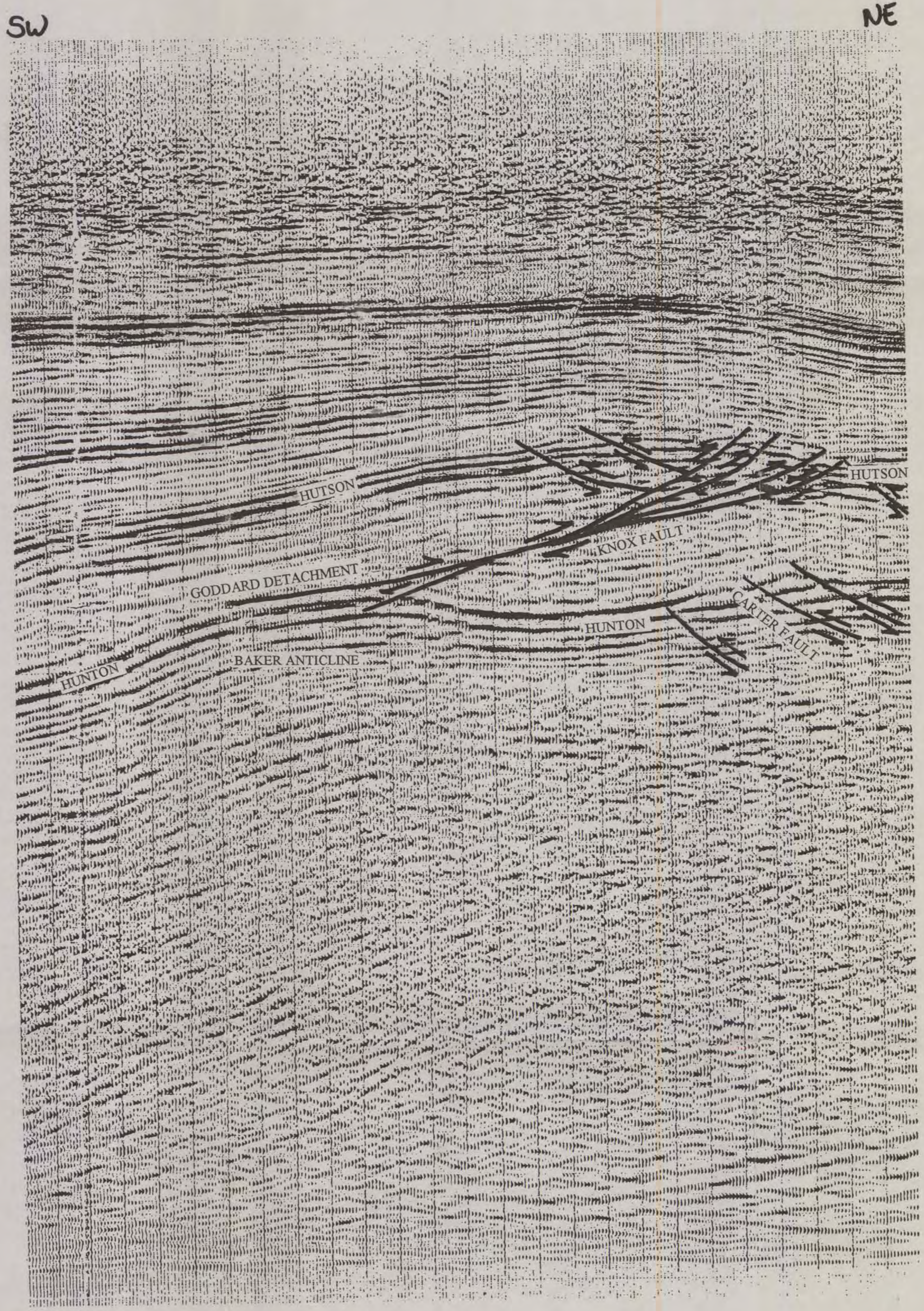


PLATE XVI	
INTERPRETED NORTHERN SEISMIC LINE	
BRIAN HOFFMAN	05/2001

PLATE XVII
UNINTERPRETED STRIKE SEISMIC LINE
BRIAN HOFFMAN 05/2001

PLATE XVIII

INTERPRETED STRIKE SEISMIC LINE

BRIAN HOFFMAN 05/2001

VITA

Brian Hoffman

Candidate for the Degree of

Master of Science

Thesis: GEOMETRY OF THE NORTHERN CARTER-KNOX STRUCTURE, ANADARKO BASIN, GRADY COUNTY, OKLAHOMA

Major Field: Geology

Biographical:

Personal Data: Born in Dallas, Texas on November 12, 1968, the son of Dennis and Judy Hoffman

Education: Graduated from Plano Senior High, Plano, Texas in May 1987; received Bachelor of Science degree in Geology from Oklahoma State University in May 1996; completed the requirements for the Master of Science degree in Geology at Oklahoma State University in May, 2001

Professional Experience: Associate Geologist: Samson Resources